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REPORT

OF THE

FORTY-FIFTH MEETING

OF THE

BRITISH ASSOCIATION

FOR THE

ADVANCEMENT OF SCIENCE;

HELD AT

BRISTOL IN AUGUST 1875.

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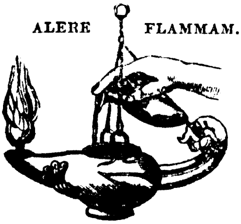
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Page 243, line 16 from bottom, *for* Mr. Charles Law *read* Mr. Channell Law.

OBJECTS AND RULES

OF

THE ASSOCIATION.

◆

OBJECTS.

The Association contemplates no interference with the ground occupied by other institutions. Its objects are:—To give a stronger impulse and a more systematic direction to scientific inquiry,—to promote the intercourse of those who cultivate Science in different parts of the British Empire, with one another and with foreign philosophers,—to obtain a more general attention to the objects of Science, and a removal of any disadvantages of a public kind which impede its progress.

RULES.

Admission of Members and Associates.

All persons who have attended the first Meeting shall be entitled to become Members of the Association, upon subscribing an obligation to conform to its Rules.

The Fellows and Members of Chartered Literary and Philosophical Societies publishing Transactions, in the British Empire, shall be entitled, in like manner, to become Members of the Association.

The Officers and Members of the Councils, or Managing Committees, of Philosophical Institutions shall be entitled, in like manner, to become Members of the Association.

All Members of a Philosophical Institution recommended by its Council or Managing Committee shall be entitled, in like manner, to become Members of the Association.

Persons not belonging to such Institutions shall be elected by the General Committee or Council, to become Life Members of the Association, Annual Subscribers, or Associates for the year, subject to the approval of a General Meeting.

Compositions, Subscriptions, and Privileges.

Life Members shall pay, on admission, the sum of Ten Pounds. They shall receive *gratuitously* the Reports of the Association which may be published after the date of such payment. They are eligible to all the offices of the Association.

ANNUAL SUBSCRIBERS shall pay, on admission, the sum of Two Pounds, and in each following year the sum of One Pound. They shall receive *gratuitously* the Reports of the Association for the year of their admission and for the years in which they continue to pay *without intermission* their Annual Subscription. By omitting to pay this Subscription in any particular year, Members of this class (Annual Subscribers) *lose for that and all future years* the privilege of receiving the volumes of the Association *gratis*: but they may resume their Membership and other privileges at any subsequent Meeting of the Association, paying on each such occasion the sum of One Pound. They are eligible to all the Offices of the Association.

ASSOCIATES for the year shall pay on admission the sum of One Pound. They shall not receive *gratuitously* the Reports of the Association, nor be eligible to serve on Committees, or to hold any office.

The Association consists of the following classes:—

1. Life Members admitted from 1831 to 1845 inclusive, who have paid on admission Five Pounds as a composition.
2. Life Members who in 1846, or in subsequent years, have paid on admission Ten Pounds as a composition.
3. Annual Members admitted from 1831 to 1839 inclusive, subject to the payment of One Pound annually. [May resume their Membership after intermission of Annual Payment.]
4. Annual Members admitted in any year since 1839, subject to the payment of Two Pounds for the first year, and One Pound in each following year. [May resume their Membership after intermission of Annual Payment.]
5. Associates for the year, subject to the payment of One Pound.
6. Corresponding Members nominated by the Council.

And the Members and Associates will be entitled to receive the annual volume of Reports, *gratis*, or to *purchase* it at reduced (or Members') price, according to the following specification, viz.:—

1. *Gratis.*—Old Life Members who have paid Five Pounds as a composition for Annual Payments, and previous to 1845 a further sum of Two Pounds as a Book Subscription, or, since 1845, a further sum of Five Pounds.

   New Life Members who have paid Ten Pounds as a composition.

   Annual Members who have not intermitted their Annual Subscription.

2. *At reduced or Members' Prices*, viz. two thirds of the Publication Price.—Old Life Members who have paid Five Pounds as a composition for Annual Payments, but no further sum as a Book Subscription.

   Annual Members who have intermitted their Annual Subscription.

   Associates for the year. [Privilege confined to the volume for that year only.]

3. Members may purchase (for the purpose of completing their sets) any of the first seventeen volumes of Transactions of the Association, *and of which more than 100 copies remain*, at one third of the Publication Price. Application to be made at the Office of the Association, 22 Albemarle Street, London, W.

Volumes not claimed within two years of the date of publication can only be issued by direction of the Council.

Subscriptions shall be received by the Treasurer or Secretaries.

Meetings.

The Association shall meet annually, for one week, or longer. The place of each Meeting shall be appointed by the General Committee two years in advance; and the Arrangements for it shall be entrusted to the Officers of the Association.

General Committee.

The General Committee shall sit during the week of the Meeting, or longer, to transact the business of the Association. It shall consist of the following persons:—

CLASS A. PERMANENT MEMBERS.

1. Members of the Council, Presidents of the Association, and Presidents of Sections for the present and preceding years, with Authors of Reports in the Transactions of the Association.

2. Members who by the publication of Works or Papers have furthered the advancement of those subjects which are taken into consideration at the Sectional Meetings of the Association. *With a view of submitting new claims under this Rule to the decision of the Council, they must be sent to the Assistant General Secretary at least one month before the Meeting of the Association. The decision of the Council on the claims of any Member of the Association to be placed on the list of the General Committee to be final.*

CLASS B. TEMPORARY MEMBERS.

1. The President for the time being of any Scientific Society publishing Transactions or, in his absence, a delegate representing him. *Claims under this Rule to be sent to the Assistant General Secretary before the opening of the Meeting.*

2. Office-bearers for the time being, or delegates, altogether not exceeding three, from Scientific Institutions established in the place of Meeting. *Claims under this Rule to be approved by the Local Secretaries before the opening of the Meeting.*

3. Foreigners and other individuals whose assistance is desired, and who are specially nominated in writing, for the Meeting of the year, by the President and General Secretaries.

4. Vice-Presidents and Secretaries of Sections.

*Organizing Sectional Committees**.

The Presidents, Vice-Presidents, and Secretaries of the several Sections are nominated by the Council, and have power to act until their names are submitted to the General Committee for election.

From the time of their nomination they constitute Organizing Committees for the purpose of obtaining information upon the Memoirs and Reports likely to be submitted to the Sections†, and of preparing Reports thereon, and on the order in which it is desirable that they should be read, to be presented to the Committees of the Sections at their first Meeting.

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* Passed by the General Committee, Edinburgh, 1871.

† *Notice to Contributors of Memoirs.*—Authors are reminded that, under an arrangement dating from 1871, the acceptance of Memoirs, and the days on which they are to be

An Organizing Committee may also hold such preliminary Meetings as the President of the Committee thinks expedient, but shall, under any circumstances, meet on the first Wednesday of the Annual Meeting, at 11 A.M., to settle the terms of their Report, after which their functions as an Organizing Committee shall cease.

Constitution of the Sectional Committees.*

On the first day of the Annual Meeting, the President, Vice-Presidents, and Secretaries of each Section having been appointed by the General Committee, these Officers, and those previous Presidents and Vice-Presidents of the Section who may desire to attend, are to meet, at 2 P.M., in their Committee Rooms, and enlarge the Sectional Committees by selecting individuals from among the Members (not Associates) present at the Meeting whose assistance they may particularly desire. The Sectional Committees thus constituted shall have power to add to their number from day to day.

The List thus formed is to be entered daily in the Sectional Minute-Book, and a copy forwarded without delay to the Printer, who is charged with publishing the same before 8 A.M. on the next day, in the Journal of the Sectional Proceedings.

Business of the Sectional Committees.

Committee Meetings are to be held on the Wednesday at 2 P.M., on the following Thursday, Friday, Saturday, Monday, and Tuesday, from 10 to 11 A.M., punctually, for the objects stated in the Rules of the Association, and specified below.

The business is to be conducted in the following manner:—

At the first meeting, one of the Secretaries will read the Minutes of last year's proceedings, as recorded in the Minute-Book, and the Synopsis of Recommendations adopted at the last Meeting of the Association and printed in the last volume of the Transactions. He will next proceed to read the Report of the Organizing Committee†. The List of Communications to be read on Thursday shall be then arranged, and the general distribution of business throughout the week shall be provisionally appointed. At the close of the Committee Meeting the Secretaries shall forward to the Printer a List of the Papers appointed to be read. The Printer is charged with publishing the same before 8 A.M. on Thursday in the Journal.

On the second day of the Annual Meeting, and the following days, the

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read, are now as far as possible determined by Organizing Committees for the several Sections *before the beginning of the Meeting*. It has therefore become necessary, in order to give an opportunity to the Committees of doing justice to the several Communications, that each Author should prepare an Abstract of his Memoir, of a length suitable for insertion in the published Transactions of the Association, and that he should send it, together with the original Memoir, by book-post, on or before ...., addressed thus—"General Secretaries, British Association, 22 Albemarle Street, London, W. For Section ......" If it should be inconvenient to the Author that his Paper should be read on any particular days, he is requested to send information thereof to the Secretaries in a separate note.

* Passed by the General Committee, Edinburgh, 1871.

†This and the following sentence were added by the General Committee, 1871.

Secretaries are to correct, on a copy of the Journal, the list of papers which have been read on that day, to add to it a list of those appointed to be read on the next day, and to send this copy of the Journal as early in the day as possible to the Printers, who are charged with printing the same before 8 A.M. next morning in the Journal. It is necessary that one of the Secretaries of each Section should call at the Printing Office and revise the proof each evening.

Minutes of the proceedings of every Committee are to be entered daily in the Minute-Book, which should be confirmed at the next meeting of the Committee.

Lists of the Reports and Memoirs read in the Sections are to be entered in the Minute-Book daily, which, with *all Memoirs and Copies or Abstracts of Memoirs furnished by Authors, are to be forwarded, at the close of the Sectional Meetings*, to the Assistant General Secretary.

The Vice-Presidents and Secretaries of Sections become *ex officio* temporary Members of the General Committee (*vide* p. xix), and will receive, on application to the Treasurer in the Reception Room, Tickets entitling them to attend its Meetings.

The Committees will take into consideration any suggestions which may be offered by their Members for the advancement of Science. They are specially requested to review the recommendations adopted at preceding Meetings, as published in the volumes of the Association and the communications made to the Sections at this Meeting, for the purposes of selecting definite points of research to which individual or combined exertion may be usefully directed, and branches of knowledge on the state and progress of which Reports are wanted; to name individuals or Committees for the execution of such Reports or researches; and to state whether, and to what degree, these objects may be usefully advanced by the appropriation of the funds of the Association, by application to Government, Philosophical Institutions, or Local Authorities.

In case of appointment of Committees for special objects of Science, it is expedient that *all Members of the Committee should be named, and one of them appointed to act as Secretary, for insuring attention to business.*

Committees have power to add to their number persons whose assistance they may require.

The recommendations adopted by the Committees of Sections are to be registered in the Forms furnished to their Secretaries, and one Copy of each is to be forwarded, without delay, to the Assistant General Secretary for presentation to the Committee of Recommendations. *Unless this be done, the Recommendations cannot receive the sanction of the Association.*

N.B.—Recommendations which may originate in any one of the Sections must *first be sanctioned by the Committee of that Section* before they can be referred to the Committee of Recommendations or confirmed by the General Committee.

Notices Regarding Grants of Money.

Committees and individuals, to whom grants of money have been entrusted by the Association for the prosecution of particular researches in Science, are required to present to each following Meeting of the Association a Report of the progress which has been made; and the Individual or the Member first named of a Committee to whom a money grant has been made must (previously to the next meeting of the Association) forward to the General

Secretaries or Treasurer a statement of the sums which have been expended, and the balance which remains disposable on each grant.

Grants of money sanctioned at any one meeting of the Association expire *a week before* the opening of the ensuing Meeting; nor is the Treasurer authorized, after that date, to allow any claims on account of such grants, unless they be renewed in the original or a modified form by the General Committee.

No Committee shall raise money in the name or under the auspices of the British Association without special permission from the General Committee to do so; and no money so raised shall be expended except in accordance with the rules of the Association.

In each Committee, the Member first named is the only person entitled to call on the Treasurer, Professor A. W. Williamson, University College, London, W.C., for such portion of the sums granted as may from time to time be required.

In grants of money to Committees, the Association does not contemplate the payment of personal expenses to the members.

In all cases where additional grants of money are made for the continuation of Researches at the cost of the Association, the sum named is deemed to include, as a part of the amount, whatever balance may remain unpaid on the former grant for the same object.

All Instruments, Papers, Drawings, and other property of the Association are to be deposited at the Office of the Association, 22 Albemarle Street, Piccadilly, London, W., when not employed in carrying on scientific inquiries for the Association.

Business of the Sections.

The Meeting Room of each Section is opened for conversation from 10 to 11 daily. *The Section Rooms and approaches thereto can be used for no notices, exhibitions, or other purposes than those of the Association.*

At 11 precisely the Chair will be taken, and the reading of communications, in the order previously made public, be commenced. At 3 P.M. the Sections will close.

Sections may, by the desire of the Committees, divide themselves into Departments, as often as the number and nature of the communications delivered in may render such divisions desirable.

A Report presented to the Association, and read to the Section which originally called for it, may be read in another Section, at the request of the Officers of that Section, with the consent of the Author.

Duties of the Doorkeepers.

1.—To remain constantly at the Doors of the Rooms to which they are appointed during the whole time for which they are engaged.

2.—To require of every person desirous of entering the Rooms the exhibition of a Member's, Associate's or Lady's Ticket, or Reporter's Ticket, signed by the Treasurer, or a Special Ticket signed by the Assistant General Secretary.

3.—Persons unprovided with any of these Tickets can only be admitted to any particular Room by order of the Secretary in that Room.

No person is exempt from these Rules, except those Officers of the Association whose names are printed.

Duties of the Messengers.

To remain constantly at the Rooms to which they are appointed, during the whole time for which they are engaged, except when employed on messages by one of the Officers directing these Rooms.

Committee of Recommendations.

The General Committee shall appoint at each Meeting a Committee, which shall receive and consider the Recommendations of the Sectional Committees, and report to the General Committee the measures which they would advise to be adopted for the advancement of Science.

All Recommendations of Grants of Money, Requests for Special Researches, and Reports on Scientific Subjects shall be submitted to the Committee of Recommendations, and not taken into consideration by the General Committee unless previously recommended by the Committee of Recommendations.

Local Committees.

Local Committees shall be formed by the Officers of the Association to assist in making arrangements for the Meetings.

Local Committees shall have the power of adding to their numbers those Members of the Association whose assistance they may desire.

Officers.

A President, two or more Vice-Presidents, one or more Secretaries, and a Treasurer shall be annually appointed by the General Committee.

Council.

In the intervals of the Meetings, the affairs of the Association shall be managed by a Council appointed by the General Committee. The Council may also assemble for the despatch of business during the week of the Meeting.

Papers and Communications.

The Author of any paper or communication shall be at liberty to reserve his right of property therein.

Accounts.

The Accounts of the Association shall be audited annually, by Auditors appointed by the General Committee.

Table showing the Places and Times of Meeting of the British Association, with Presidents, Vice-Presidents, and Local Secretaries, from its Commencement.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
The EARL FITZWILLIAM, D.C.L., F.R.S., F.G.S., &c. YORK, September 27, 1831.	Rev. W. Vernon Harcourt, M.A., F.R.S., F.G.S.	William Gray, jun., F.G.S. Professor Phillips, M.A., F.R.S., F.G.S.
The REV. W. BUCKLAND, D.D., F.R.S., F.G.S., &c. OXFORD, June 19, 1832.	Sir David Brewster, F.R.S. L. & E., &c. Rev. W. Whewell, F.R.S., Pres. Geol. Soc.	Professor Daubeny, M.D., F.R.S., &c. Rev. Professor Powell, M.A., F.R.S., &c.
The REV. ADAM SEDGWICK, M.A., V.P.R.S., V.P.G.S. CAMBRIDGE, June 25, 1833.	G. B. Airy, F.R.S., Astronomer Royal, &c. John Dalton, D.C.L., F.R.S.	Rev. Professor Henslow, M.A., F.L.S., F.G.S. Rev. W. Whewell, F.R.S.
SIR T. MACDOUGALL BRISBANE, K.C.B., D.C.L., F.R.S. L. & E. EDINBURGH, September 8, 1834.	Sir David Brewster, F.R.S., &c. Rev. T. R. Robinson, D.D.	Professor Forbes, F.R.S. L. & E., &c. Sir John Robinson, Sec. R.S.E.
The REV. PROVOST LLOYD, LL.D. DUBLIN, August 10, 1835.	Viscount Oxmantown, F.R.S., F.R.A.S. Rev. W. Whewell, F.R.S., &c	Sir W. R. Hamilton, Astron. Royal of Ireland, &c. Rev. Professor Lloyd, F.R.S.
The MARQUIS OF LANSDOWNE, D.C.L., F.R.S., &c. BRISTOL, August 22, 1836.	The Marquis of Northampton, F.R.S. Rev. W. D. Conybeare, F.R.S. F.G.S. J. C. Prichard, M.D., F.R.S	Professor Daubeny, M.D., F.R.S., &c. V. F. Hovenden, Esq.
The EARL OF BURLINGTON, F.R.S., F.G.S., Chancellor of the University of London LIVERPOOL, September 11, 1837.	The Bishop of Norwich, P.L.S., F.G.S. John Dalton, D.C.L., F.R.S. Sir Philip de Grey Egerton, Bart., F.R.S., F.G.S. Rev. W. Whewell, F.R.S.	Professor Traill, M.D. Wm. Wallace Currie, Esq. Joseph N. Walker, Pres. Royal Institution, Liverpool.
The DUKE OF NORTHUMBERLAND, F.R.S., F.G.S., &c. NEWCASTLE-ON-TYNE, August 20, 1838.	The Bishop of Durham, F.R.S., F.S.A. The Rev. W. Vernon Harcourt, F.R.S., &c. Prideaux John Selby, Esq., F.R.S.E.	John Adamson, F.L.S., &c. Wm. Hutton, F.G.S. Professor Johnston, M.A., F.R.S.
The REV. W. VERNON HARCOURT, M.A., F.R.S., &c. BIRMINGHAM, August 26, 1839.	Marquis of Northampton. Earl of Dartmouth. The Rev. T. R. Robinson, D.D. John Corrie, Esq., F.R.S. Very Rev. Principal Macfarlane	George Barker, Esq., F.R.S. Peyton Blakiston, M.D. Joseph Hodgson, Esq., F.R.S. Follett Osler, Esq.
The MARQUIS OF BREADALBANE, F.R.S. GLASGOW, September 17, 1840.	Major-General Lord Greenock, F.R.S.E. Sir David Brewster, F.R.S. Sir T. M. Brisbane, Bart., F.R.S. The Earl of Mount Edgecumbe.	Andrew Liddell, Esq. Rev. J. P. Nicol, LL.D. John Strang, Esq.
The REV. PROFESSOR WHEWELL, F.R.S., &c. PLYMOUTH, July 29, 1841.	The Earl of Morley. Lord Eliot, M.P. Sir C. Lemon, Bart. Sir D. T. Acland, Bart.	W. Snow Harris, Esq., F R.S. Col. Hamilton Smith, F.L S. Robert Were Fox, Esq. Richard Taylor, jun., Esq.
The LORD FRANCIS EGERTON, F.G.S. MANCHESTER, June 23, 1842.	John Dalton, D.C.L., F.R.S. Hon. and Rev. W. Herbert, F.L.S., &c. Rev. A. Sedgwick, M.A., F.R.S. W. C. Henry, M.D., F.R.S. Sir Benjamin Heywood, Bart.	Peter Clare, Esq , F.R.A.S. W. Fleming, M.D. James Heywood, Esq., F.R.S.
The EARL OF ROSSE, F.R.S. CORK, August 17, 1843.	Earl of Listowel. Viscount Adare Sir W. R. Hamilton, Pres.R.I.A. Rev. T. R. Robinson, D.D.	Professor John Stevelly, M.A. Rev. Jos. Carson, F.T.C. Dublin. William Keleher, Esq. Wm. Clear, Esq.
The REV. G. PEACOCK, D.D. (Dean of Ely), F.R.S. YORK, September 26, 1844.	Earl Fitzwilliam, F.R.S. Viscount Morpeth, F.G.S. The Hon. John Stuart Wortley, M.P. Sir David Brewster, K.H., F.R.S. Michael Faraday, Esq., D.C.L., F.R.S. Rev. W. V. Harcourt, F.R.S.	William Hatfeild, Esq., F.G.S. Thomas Meynell, Esq., F.L.S. Rev. W. Scoresby, LL.D., F.R.S. William West, Esq.

SIR JOHN F. W. HERSCHEL, Bart., F.R.S., &c.…… CAMBRIDGE, June 19, 1845.	The Earl of Hardwicke. The Bishop of Norwich…… Rev. J. Graham, D.D. Rev. G. Ainslie, D.D. …… G. B. Airy, Esq., M.A., D.C.L., F.R.S.…… The Rev. Professor Sedgwick, M.A., F.R.S. ……	William Hopkins, Esq., M.A., F.R.S. Professor Ansted, M.A., F.R.S.
SIR RODERICK IMPEY MURCHISON, G.C.St.S., F.R.S. SOUTHAMPTON, September 10, 1846.	The Marquis of Winchester. The Earl of Yarborough, D.C.L.…… Lord Ashburton, D.C.L. Viscount Palmerston, M.P.…… Right Hon. Charles Shaw Lefevre, M.P.…… Sir George T. Staunton, Bart., M.P., D.C.L., F.R.S.…… The Lord Bishop of Oxford, F.R.S. …… Professor Owen, M.D., F.R.S. Professor Powell, F.R.S.……	Henry Clark, M.D. T. H. C. Moody, Esq.
SIR ROBERT HARRY INGLIS, Bart., D.C.L., F.R.S., M.P. for the University of Oxford …… OXFORD, June 23, 1847.	The Earl of Rosse, F.R.S. The Lord Bishop of Oxford, F.R.S.…… The Vice-Chancellor of the University …… Thomas G. Bucknall Estcourt, Esq., D.C.L., M.P. for the University of Oxford. Very Rev. the Dean of Westminster, D.D., F.R.S.…… Professor Daubeny, M.D., F.R.S. The Rev. Prof. Powell, M.A., F.R.S.	Rev. Robert Walker, M.A., F.R.S. H. Wentworth Acland, Esq., B.M.
The **MARQUIS OF NORTHAMPTON**, President of the Royal Society, &c. …… SWANSEA, August 9, 1848.	The Marquis of Bute, K.T. Viscount Adare, F.R.S.…… Sir H. T. De la Beche, F.R.S., Pres. G.S. …… The Very Rev. the Dean of Llandaff, F.R.S. …… Lewis W. Dillwyn, Esq., F.R.S. W. R. Grove, Esq., F.R.S.…… J. H. Vivian, Esq., M.P., F.R.S. The Lord Bishop of St. David's……	Matthew Moggridge, Esq. D. Nicol, M.D.
The **REV. T. R. ROBINSON**, D.D., M.R.I.A., F.R.A.S. BIRMINGHAM, September 12, 1849.	The Earl of Harrowby. The Lord Wrottesley, F.R.S.…… Right Hon. Sir Robert Peel, Bart., M.P., D.C.L., F.R.S.…… Charles Darwin, Esq., M.A., F.R.S., Sec. G.S.…… Professor Faraday, D.C.L., F.R.S. …… Sir David Brewster, K.H., LL.D., F.R.S. Rev. Prof. Willis, M.A., F.R.S.	Captain Tindal, R.N. William Wills, Esq. Bell Fletcher, Esq., M.D. James Chance, Esq.
SIR DAVID BREWSTER, K.H., LL.D., F.R.S. L. & E., Principal of the United College of St. Salvator and St. Leonard, St. Andrews…… EDINBURGH, July 21, 1850.	Right Hon. the Lord Provost of Edinburgh …… The Earl of Cathcart, K.C.B., F.R.S.E. …… The Earl of Rosebery, K.T., D.C.L., F.R.S.…… Right Hon. David Boyle (Lord Justice-General), F.R.S.E. …… General Sir Thomas M. Brisbane, Bart., D.C.L., F.R.S., Pres. R.S.E.…… Very Rev. John Lee, D.D., V.P.R.S.E., Principal of the University of Edinburgh. Professor W. P. Alison, M.D., V.P.R.S.E. …… Professor J. D. Forbes, F.R.S., Sec. R.S.E. ……	Rev. Professor Kelland, M.A., F.R.S.L. & E. Professor Balfour, M.D., F.R.S.E., F.L.S. James Tod, Esq., F.R.S.E.
GEORGE BIDDELL AIRY, Esq., D.C.L., F.R.S., Astronomer Royal …… IPSWICH, July 2, 1851.	The Lord Rendlesham, M.P. The Lord Bishop of Norwich …… Rev. Professor Sedgwick, M.A., F.R.S.…… Rev. Professor Henslow, M.A., F.L.S.…… Sir John P. Boileau, Bart., F.R.S. Sir William F. F. Middleton, Bart. J. C. Cobbold, Esq., M.P. T. B. Western, Esq.……	Charles May, Esq., F.R.A.S. Dillwyn Sims, Esq. George Arthur Biddell, Esq. George Ransome, Esq., F.L.S.
COLONEL EDWARD SABINE, Royal Artillery, Treas. & V.P. of the Royal Society …… BELFAST, September 1, 1852.	The Earl of Enniskillen, D.C.L., F.R.S.…… The Earl of Rosse, M.R.I.A., Pres. R.S.…… Sir Henry T. De la Beche, F.R.S.…… Rev. Edward Hincks, D.D., M.R.I.A.…… Rev. P. S. Henry, D.D., Pres. Queen's College, Belfast …… Rev. T. R. Robinson, D.D., Pres. R.I.A., F.R.A.S. …… Professor G. G. Stokes, F.R.S. Professor Stevelly, LL.D.……	W. J. C. Allen, Esq. William M'Gee, M.D. Professor W. P. Wilson.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
WILLIAM HOPKINS, Esq., M.A., V.P.R.S., F.G.S., & Pres. Camb. Phil. Society. HULL, September 7, 1853.	The Earl of Carlisle, F.R.S. Lord Londesborough, F.R.S. Professor Faraday, D.C.L., F.R.S. Rev. Prof. Sedgwick, M.A., F.R.S. Charles Frost, Esq., F.S.A., Pres. of the Hull Lit. and Philos. Society. William Spence, Esq., F.R.S. Lieut.-Col. Sykes, F.R.S. Professor Wheatstone, F.R.S.	Henry Cooper, M.D., V.P. Hull. Lit. & Phil. Society. Bethel Jacobs, Esq., Pres. Hull Mechanics' Inst.
The **EARL OF HARROWBY**, F.R.S. LIVERPOOL, September 20, 1854.	The Lord Wrottesley, M.A., F.R.S., F.R.A.S. Sir Philip de Malpas Grey Egerton, Bart., M.P., F.R.S., F.G.S. Professor Owen, M.D., LL.D., F.R.S., F.L.S., F.G.S. Rev. Professor Whewell, D.D., F.R.S., Hon. M.R.I.A., F.G.S., Master of Trinity College, Cambridge William Lassell, Esq., F.R.S.L. & E., F.R.A.S. Joseph Brooks Yates, F.S.A., F.R.G.S.	Joseph Dickinson, M.D., F.R.S. Thomas Inman, M.D.
The **DUKE OF ARGYLL**, F.R.S., F.G.S. GLASGOW, September 12, 1855.	The Very Rev. Principal Macfarlane, D.D. Sir William Jardine, Bart., F.R.S.E. Sir Charles Lyell, M.A., LL.D., F.R.S. James Smith, Esq., F.R.S. L. & E. Walter Crum, Esq., F.R.S. Thomas Graham, Esq., M.A., F.R.S., Master of the Royal Mint Professor William Thomson, M.A., F.R.S.	John Strang, LL.D. Professor Thomas Anderson, M.D. William Gourlie, Esq.
CHARLES G. B. DAUBENY, M.D., LL.D., F.R.S., Professor of Botany in the University of Oxford CHELTENHAM, August 6, 1856.	The Earl of Ducie, F.R.S., F.G.S. The Lord Bishop of Gloucester and Bristol Sir Roderick I. Murchison, G.C.St S., D.C.L., F.R.S. Thomas Barwick Lloyd Baker, Esq. The Rev. Francis Close, M.A.	Capt. Robinson, R.A. Richard Beamish, Esq., F.R.S. John West Hugall, Esq.
The **REV. HUMPHREY LLOYD**, D.D., D.C.L., F.R.S. L. & E., V.P.R.I.A. DUBLIN, August 26, 1857.	The Right Honourable the Lord Mayor of Dublin The Provost of Trinity College, Dublin The Marquis of Kildare. Lord Talbot de Malahide The Lord Chancellor of Ireland The Lord Chief Baron, Dublin Sir William R. Hamilton, LL.D., F.R.A.S., Astronomer Royal of Ireland Lieut.-Colonel Larcom, R.E., LL.D., F.R.S. Richard Griffith, Esq., LL.D., M.R.I.A., F.R.S.E., F.G.S.	Lundy E. Foote, Esq. Rev. Professor Jellett, F.T.C.D. W. Neilson Hancock, LL.D.
RICHARD OWEN, M.D., D.C.L., V.P.R.S., F.L.S., F.G.S., Superintendent of the Natural-History Departments of the British Museum LEEDS, September 22, 1858.	The Lord Monteagle, F.R.S. The Lord Viscount Goderich, M.P., F.R.G.S. The Right Hon. M. T. Baines, M.A., M.P. Sir Philip de Malpas Grey Egerton, Bart., M.P., F.R.S., F.G.S. The Rev. W. Whewell, D.D., F.R.S., Hon. M.R.I.A., F.G.S., F.R.A.S., Master of Trinity College, Cambridge James Garth Marshall, Esq., M.A., F.G.S. R. Monckton Milnes, Esq., D.C.L., M.P., F.R.G.S.	Rev. Thomas Hincks, B.A. W. Sykes Ward, Esq., F.C.S. Thomas Wilson, Esq., M.A.
HIS ROYAL HIGHNESS THE PRINCE CONSORT ABERDEEN, September 14, 1859.	The Duke of Richmond, K.G., F.R.S. The Earl of Aberdeen, LL.D., K.G., K.T., F.R.S. The Lord Provost of the City of Aberdeen Sir John F. W. Herschel, Bart., M.A., D.C.L., F.R.S. Sir David Brewster, K.H., D.C.L., F.R.S. Sir Roderick I. Murchison, G.C.St.S., D.C.L., F.R.S. The Rev. W. V. Harcourt, M.A., F.R.S. The Rev. T. R. Robinson, D.D., F.R.S. A. Thomson, Esq., LL.D., F.R.S., Convener of the County of Aberdeen.	Professor J. Nicol, F.R.S.E., F.G.S. Professor Fuller, M.A. John F. White, Esq.

The LORD WROTTESLEY, M.A., V.P.R.S., F.R.A.S. OXFORD, June 27, 1860.	The Earl of Derby, K.G., P.C., D.C.L., Chancellor of the Univ. of Oxford The Rev. F. Jeune, D.C.L., Vice-Chancellor of the University of Oxford The Duke of Marlborough, D.C.L., F.G.S., Lord Lieutenant of Oxfordshire The Earl of Rosse, K.P., M.A., F.R.S., F.R.A.S. The Lord Bishop of Oxford, D.D., F.R.S. The Very Rev. H. G. Liddell, D.D., Dean of Christ Church, Oxford Professor Daubeny, M.D., LL.D., F R.S., F.L.S., F.G.S. Professor Acland, M.D., F.R.S. Professor Donkin, M.A., F.R.S., F.R.A.S.	George Rolleston, M.D., F.L.S. H. J. S. Smith, Esq., M.A., F C.S. George Griffith, Esq., M.A., F.C.S.
WILLIAM FAIRBAIRN, Esq., LL.D., C.E., F.R.S. MANCHESTER, September 4, 1861.	The Earl of Ellesmere, F.R.G.S. The Lord Stanley, M.P., D.C.L., F.R.G.S. The Lord Bishop of Manchester, D.D., F.R.S., F.G.S. Sir Philip de M. Grey Egerton, Bart., M.P., F.R.S., F.G.S. Sir Benjamin Heywood, Bart., F.R.S. Thomas Bazley, Esq., M.P. James Aspinall Turner, Esq., M.P. James Prescott Joule, Esq., LL.D., F.R.S., Pres. Lit. & Phil. Soc. Manchester Professor E. Hodgkinson, F.R.S., M.R.I.A., M.I.C.E. Joseph Whitworth, Esq., F.R.S., M.I.C.E.	R. D. Darbishire, Esq., B.A., F.G.S. Alfred Neild, Esq. Arthur Ransome, Esq., M.A. Professor H. E. Roscoe, B.A.
The REV. R. WILLIS, M.A., F.R.S., Jacksonian Professor of Natural and Experimental Philosophy in the University of Cambridge CAMBRIDGE, October 1, 1862.	The Rev. the Vice-Chancellor of the University of Cambridge The Very Rev. Harvey Goodwin, D.D., Dean of Ely The Rev. W. Whewell, D.D., F.R.S., Master of Trinity College, Cambridge The Rev. Professor Sedgwick, M.A., D.C.L., F.R.S. Rev. J. Challis, M.A., F.R.S. G. B. Airy, Esq., M.A., D.C.L., F.R.S., Astronomer Royal Professor G. G. Stokes, M.A., D C.L., Sec. R.S. Professor J. C. Adams, M.A., D.C.L., F.R.S., Pres. C.P.S.	Professor C. C. Babington, M.A., F.R.S., F.L.S. Professor G. D. Liveing, M.A. The Rev. N. M. Ferrers, M.A.
SIR W. ARMSTRONG, C.B., LL.D., F.R.S. NEWCASTLE-ON-TYNE, August 26, 1863.	Sir Walter C. Trevelyan, Bart., M.A. Sir Charles Lyell, LL.D., D.C.L., F.R.S., F.G.S. Hugh Taylor, Esq., Chairman of the Coal Trade Isaac Lowthian Bell, Esq., Mayor of Newcastle Nicholas Wood, Esq., President of the Northern Institute of Mining Engineers Rev. Temple Chevallier, B.D., F.R.A.S. William Fairbairn, Esq., LL.D., F.R.S.	A. Noble, Esq. Augustus H. Hunt, Esq. R. C. Clapham, Esq.
SIR CHARLES LYELL, Bart., M.A., D.C.L., F.R.S. BATH, September 14, 1864.	The Right Hon. the Earl of Cork and Orrery, Lord Lieutenant of Somersetshire The Most Noble the Marquis of Bath The Right Hon. Earl Nelson The Right Hon. Lord Portman The Very Reverend the Dean of Hereford The Venerable the Archdeacon of Bath W. Tite, Esq., M.P., F.R.S., F.G.S., F.S.A. A. E. Way, Esq., M.P. Francis H. Dickinson, Esq. W. Sanders, Esq., F.R.S., F.G.S.	C. Moore, Esq., F.G.S. C. E. Davis, Esq. The Rev. H. H. Winwood, M.A.

PRESIDENTS.	VICE-PRESIDENTS.	LOCAL SECRETARIES.
JOHN PHILLIPS, Esq., M.A., LL.D., F.R.S., F.G.S., Professor of Geology in the University of Oxford BIRMINGHAM, September 6, 1865.	The Right Hon. the Earl of Lichfield, Lord-Lieutenant of Staffordshire. The Right Hon. the Earl of Dudley The Right Hon. Lord Leigh, Lord-Lieutenant of Warwickshire The Right Hon. Lord Lyttelton, Lord-Lieutenant of Worcestershire The Right Hon. Lord Wrottesley, M.A., D.C.L., F.R.S., F.R.A.S. The Right Reverend the Lord Bishop of Worcester The Right Hon. C. B. Adderley, M.P. William Scholefield, Esq., M.P. J. T. Chance, Esq. F. Osler, Esq., F.R.S. The Rev. Charles Evans, M.A.	William Mathews, Esq., jun., F.G.S. John Henry Chamberlain, Esq. The Rev. G. D. Boyle, M.A.
WILLIAM R. GROVE, Esq., Q.C., M.A., F.R.S. NOTTINGHAM, August 22, 1866.	His Grace the Duke of Devonshire, Lord-Lieutenant of Derbyshire His Grace the Duke of Rutland, Lord-Lieutenant of Leicestershire The Right Hon. Lord Belper, Lord-Lieutenant of Nottinghamshire The Right Hon. J. E. Denison, M.P. J. C. Webb, Esq., High-Sheriff of Nottinghamshire Thomas Graham, Esq., F.R.S., Master of the Mint Joseph Hooker, M.D., F.R.S., F.L.S. John Russell Hinds, Esq., F.R.S., F.R.A.S. T. Close, Esq.	Dr. Robertson. Edward J. Lowe, Esq., F.R.A.S., F.L.S. The Rev. J. F. M'Callan, M.A.
HIS GRACE THE DUKE OF BUCCLEUCH, K.G., D.C.L., F.R.S. DUNDEE, September 4, 1867.	The Right Hon. the Earl of Airlie, K.T. The Right Hon. the Lord Kinnaird, K.T. Sir John Ogilvy, Bart., M.P. Sir Roderick I. Murchison, Bart., K.C.B., LL.D., F.R.S., F.G.S., &c. Sir David Baxter, Bart. Sir David Brewster, D.C.L., F.R.S., Principal of the University of Edinburgh James D. Forbes, LL.D., F.R.S., Principal of the United College of St. Salvator and St. Leonard, University of St Andrews	J. Henderson, Esq., jun. John Austin Lake Gloag, Esq. Patrick Anderson, Esq.
JOSEPH DALTON HOOKER, M.D., D.C.L., F.R.S., F.L.S. NORWICH, August 19, 1868.	The Right Hon. the Earl of Leicester, Lord-Lieutenant of Norfolk Sir John Peter Boileau, Bart., F.R.S. The Rev. Adam Sedgwick, M.A., LL.D., F.R.S., F.G.S., &c., Woodwardian Professor of Geology in the University of Cambridge Sir John Lubbock, Bart., F.R.S., F.L.S., F.G.S. John Couch Adams, Esq., M.A., D.C.L., F.R.S., F.R.A.S., Lowndean Professor of Astronomy and Geometry in the University of Cambridge. Thomas Brightwell, Esq.	Dr. Donald Dalrymple. Rev. Joseph Crompton, M.A. Rev. Canon Hinds Howell.
PROFESSOR GEORGE G. STOKES, D.C.L., F.R.S. EXETER, August 18, 1869.	The Right Hon. the Earl of Devon The Right Hon. Sir Stafford H. Northcote, Bart., C.B., M.P., &c. Sir John Bowring, LL.D., F.R.S. William B. Carpenter, M.D., F.R.S., F.L.S. Robert Were Fox, Esq., F.R.S. W. H. Fox Talbot, Esq., M.A., LL.D., F.R.S., F.L.S.	Henry S. Ellis, Esq., F.R.A.S. John C. Bowring, Esq. The Rev. R. Kirwan.
PROFESSOR T. H. HUXLEY, LL.D., F.R.S., F.G.S. LIVERPOOL, September 14, 1870.	The Right Hon. the Earl of Derby, LL.D., F.R.S. Sir Philip de M. Grey Egerton, Bart., M.P. The Right Hon. W. E. Gladstone, D.C.L., M.P. S. R. Graves, Esq., M.P. Sir Joseph Whitworth, Bart., LL.D., D.C.L., F.R.S. James P. Joule, LL.D., D.C.L., F.R.S. Joseph Mayer, Esq., F.S.A., F.R.G.S.	Rev. W. Banister. Reginald Harrison, Esq. Rev. Henry H. Higgins, M.A. Rev. Dr. A. Hume, F.S.A.

PROFESSOR SIR WILLIAM THOMSON, M.A., LL.D., F.R.SS.L. & E. EDINBURGH, August 2, 1871.	His Grace the Duke of Buccleuch, K G., D.C.L., F.R.S. The Right Hon. the Lord Provost of Edinburgh The Right Hon. John Inglis, LL D , Lord Justice-General of Scotland. Sir Alexander Grant, Bart., M.A., Principal of the University of Edinburgh Sir Roderick I. Murchison, Bart., K C.B., G.C.St.S., D.C.L., F.R.S. Sir Charles Lyell, Bart., D C.L., F.R S , F.G.S. Dr. Lyon Playfair, C B , M.P., F.R.S. Professor Christison, M.D., D C L., Pres. R.S.E. Professor Balfour, F.R.SS.L. & E.	Professor A. Crum Brown, M.D., F.R.S.E. J. D. Marwick, Esq., F.R.S.E.
DR. W. B. CARPENTER, LL.D., F R S , F L.S. BRIGHTON, August 14, 1872.	The Earl of Chichester, Lord-Lieutenant of the County of Sussex The Duke of Norfolk The Right Hon. the Duke of Richmond, K.G., P.C., D.C L. The Right Hon the Duke of Devonshire, K.G , D.C.L., F.R.S. Sir John Lubbock, Bart., M.P., F.R.S., F.L.S , F G S Dr Sharpey, LL.D., Sec R S , F L S. J. Prestwich, Esq , F.R.S., Pres. G.S.	Charles Carpenter, Esq. The Rev. Dr. Griffith. Henry Willett, Esq
PROFESSOR ALEXANDER W. WILLIAMSON, LL.D., F.R.S., F.C.S. BRADFORD, September 17, 1873	The Right Hon. the Earl of Rosse, F.R.S., F.R.A.S. Lord Houghton, D.C L., F.R.S. The Right Hon. W. E. Forster, M P. The Mayor of Bradford J. P. Gassiot. Esq., D.C.L., F.R S. Professor Phillips, D.C.L., F R.S Sir John Hawkshaw, F.R.S., F.G.S.	The Rev. J. R. Campbell, D.D. Richard Goddard, Esq. Peile Thompson, Esq.
PROFESSOR J. TYNDALL, D.C.L., LL D , F.R.S BELFAST, August 19, 1874	The Right Hon. the Earl of Enniskillen, D.C.L., F.R.S. The Right Hon. the Earl of Rosse, F.R.S. Sir Richard Wallace, Bart., M.P. Rev. Dr. Henry Rev. Dr. Robinson, F.R.S. Dr. Andrews, F.R.S. Professor Stokes, D.C.L., F.R.S.	W. Quartus Ewart, Esq. Dr. T. Redfern. T. Sinclair, Esq.
SIR JOHN HAWKSHAW, C.E., F.R.S., F.G.S. BRISTOL, August 25, 1875.	The Right Hon. the Earl of Ducie, F.R.S., F.G.S. The Right Hon. Sir Stafford H. Northcote, Bart., C.B., M.P., F.R.S. The Mayor of Bristol Major-General Sir Henry C. Rawlinson, K C.B., LL.D , F.R.S., F.R.G.S. Dr. W. B. Carpenter, LL.D., F.R.S., F.L.S., F.G.S. W. Sanders, Esq., F.R.S., F.G.S.	W. Lant Carpenter, Esq., B.A., B.Sc., F.C.S. John H. Clarke, Esq.
PROFESSOR THOMAS ANDREWS, M.D., LL.D., F.R.S., Hon. F.R.S.E. GLASGOW, September 6, 1876.	His Grace the Duke of Argyll, K.T., LL.D., F.R.S.L. & E., F.G.S. The Hon. the Lord Provost of Glasgow Sir William Stirling Maxwell, Bart., M.A., M.P. Sir William Thomson, M.A., LL.D , D C.L., F.R.S L. & E. Professor Allen Thomson, M.D., LL.D., F.R.S.L. & E. Professor A C. Ramsay, LL D., F.R.S., F.G.S	Dr. W. G. Blackie, F R.G.S. James Grahame, Esq. J. D. Marwick, Esq.

Presidents and Secretaries of the Sections of the Association.

Date and Place.	Presidents.	Secretaries.
	MATHEMATICAL AND PHYSICAL SCIENCES.	
	COMMITTEE OF SCIENCES, I.—MATHEMATICS AND GENERAL PHYSICS.	
1832. Oxford	Davies Gilbert, D.C.L., F.R.S.	Rev. H. Coddington.
1833. Cambridge	Sir D. Brewster, F.R.S.	Prof. Forbes.
1834. Edinburgh	Rev. W. Whewell, F.R.S.	Prof. Forbes, Prof. Lloyd.
	SECTION A.—MATHEMATICS AND PHYSICS.	
1835. Dublin	Rev. Dr. Robinson	Prof. Sir W. R. Hamilton, Prof. Wheatstone.
1836. Bristol	Rev. William Whewell, F.R.S.	Prof. Forbes, W. S. Harris, F. W. Jerrard.
1837. Liverpool	Sir D. Brewster, F.R.S.	W. S. Harris, Rev. Prof. Powell, Prof. Stevelly.
1838. Newcastle	Sir J. F. W. Herschel, Bart., F.R.S.	Rev. Prof. Chevallier, Major Sabine, Prof. Stevelly.
1839. Birmingham	Rev. Prof. Whewell, F.R.S.	J. D. Chance, W. Snow Harris Prof. Stevelly.
1840. Glasgow	Prof. Forbes, F.R.S.	Rev. Dr. Forbes, Prof. Stevelly, Arch. Smith.
1841. Plymouth	Rev. Prof. Lloyd, F.R.S.	Prof. Stevelly.
1842. Manchester	Very Rev. G. Peacock, D.D., F.R.S.	Prof. M'Culloch, Prof. Stevelly, Rev. W. Scoresby.
1843. Cork	Prof. M'Culloch, M.R.I.A.	J. Nott, Prof. Stevelly.
1844. York	The Earl of Rosse, F.R.S.	Rev. Wm. Hey, Prof. Stevelly.
1845. Cambridge	The Very Rev. the Dean of Ely	Rev. H. Goodwin, Prof. Stevelly, G. G. Stokes.
1846. Southampton	Sir John F. W. Herschel, Bart., F.R.S.	John Drew, Dr. Stevelly, G. G. Stokes.
1847. Oxford	Rev. Prof. Powell, M.A., F.R.S.	Rev. H. Price, Prof. Stevelly, G. G. Stokes.
1848. Swansea	Lord Wrottesley, F.R.S.	Dr. Stevelly, G. G. Stokes.
1849. Birmingham	William Hopkins, F.R.S.	Prof. Stevelly, G. G. Stokes, W. Ridout Wills.
1850. Edinburgh	Prof. J. D. Forbes, F.R.S., Sec. R.S.E.	W. J. Macquorn Rankine, Prof. Smyth, Prof. Stevelly, Prof. G. G. Stokes.
1851. Ipswich	Rev. W. Whewell, D.D., F.R.S., &c.	S. Jackson, W. J. Macquorn Rankine, Prof. Stevelly, Prof. G. G. Stokes.
1852. Belfast	Prof. W. Thomson, M.A., F.R.S. L. & E.	Prof. Dixon, W. J. Macquorn Rankine, Prof. Stevelly, J. Tyndall.
1853. Hull	The Dean of Ely, F.R.S.	B. Blaydes Haworth, J. D. Sollitt, Prof. Stevelly, J. Welsh.
1854. Liverpool	Prof. G. G. Stokes, M.A., Sec. R.S.	J. Hartnup, H. G. Puckle, Prof. Stevelly, J. Tyndall, J. Welsh.
1855. Glasgow	Rev. Prof. Kelland, M.A., F.R.S. L. & E.	Rev. Dr. Forbes, Prof. D. Gray, Prof. Tyndall.
1856. Cheltenham	Rev. R. Walker, M.A., F.R.S.	C. Brooke, Rev. T. A. Southwood, Prof. Stevelly, Rev. J. C. Turnbull.
1857. Dublin	Rev. T. R. Robinson, D.D., F.R.S., M.R.I.A.	Prof. Curtis, Prof. Hennessy, P. A. Ninnis, W. J. Macquorn Rankine, Prof. Stevelly.
1858. Leeds	Rev. W. Whewell, D.D., V.P.R.S.	Rev. S. Earnshaw, J. P. Hennessy, Prof. Stevelly, H. J. S. Smith, Prof. Tyndall.

Date and Place.	Presidents.	Secretaries.
1859. Aberdeen ...	The Earl of Rosse, M.A., K.P., F.R.S.	J. P. Hennessy, Prof. Maxwell, H. J. S. Smith, Prof. Stevelly.
1860. Oxford	Rev. B. Price, M.A., F.R.S.......	Rev. G. C. Bell, Rev. T. Rennison, Prof. Stevelly.
1861. Manchester.	G. B. Airy, M.A., D.C.L., F.R.S.	Prof. R. B. Clifton, Prof. H. J. S. Smith, Prof. Stevelly.
1862. Cambridge..	Prof. G. G. Stokes, M.A., F.R.S.	Prof. R. B. Clifton, Prof. H. J. S. Smith, Prof. Stevelly.
1863. Newcastle..	Prof. W. J. Macquorn Rankine, C.E., F.R.S.	Rev. N. Ferrers, Prof. Fuller, F. Jenkin, Prof. Stevelly, Rev. C. T. Whitley.
1864. Bath	Prof. Cayley, M.A., F.R.S., F.R.A.S.	Prof. Fuller, F. Jenkin, Rev. G. Buckle, Prof. Stevelly.
1865. Birmingham	W. Spottiswoode, M.A., F.R.S., F.R.A.S.	Rev. T. N. Hutchinson, F. Jenkin, G. S. Mathews, Prof. H. J. S. Smith, J. M. Wilson.
1866. Nottingham	Prof. Wheatstone, D.C.L., F.R.S.	Fleeming Jenkin, Prof. H. J. S. Smith, Rev. S. N. Swann.
1867. Dundee......	Prof. Sir W. Thomson, D.C.L., F.R.S.	Rev. G. Buckle, Prof. G. C. Foster, Prof. Fuller, Prof. Swan.
1868. Norwich ..	Prof. J. Tyndall, LL.D., F.R.S...	Prof. G. C. Foster, Rev. R. Harley, R. B. Hayward.
1869. Exeter	Prof. J. J. Sylvester, LL.D., F.R.S.	Prof G. C. Foster, R. B. Hayward, W. K. Clifford.
1870. Liverpool..	J. Clerk Maxwell, M.A., LL.D., F.R.S.	Prof W. G. Adams, W. K. Clifford, Prof. G. C. Foster, Rev. W. Allen Whitworth.
1871. Edinburgh .	Prof. P. G. Tait, F.R.S.E.	Prof. W. G. Adams, J. T. Bottomley, Prof. W. K. Clifford, Prof. J. D. Everett, Rev. R. Harley.
1872. Brighton ..	W. De La Rue, D.C.L., F.R.S...	Prof. W. K. Clifford, J. W. L. Glaisher, Prof. A. S. Herschel, G. F. Rodwell.
1873. Bradford ...	Prof. H. J. S. Smith, F.R.S......	Prof. W. K. Clifford, Prof. Forbes, J. W. L Glaisher, Prof. A. S. Herschel.
1874. Belfast	Rev. Prof. J. H. Jellett, M.A., M.R.I.A.	J. W. L. Glaisher, Prof. Herschel, Randal Nixon, J. Perry, G. F. Rodwell.
1875. Bristol	Prof Balfour Stewart, M.A., LL D., F.R.S.	Prof. W. F. Barrett, J. W. L. Glaisher, C. T. Hudson, G. F. Rodwell.

CHEMICAL SCIENCE.

COMMITTEE OF SCIENCES, II.—CHEMISTRY, MINERALOGY.

1832. Oxford	John Dalton, D.C.L., F.R.S......	James F. W. Johnston.
1833. Cambridge..	John Dalton, D.C.L., F.R.S......	Prof. Miller.
1834. Edinburgh...	Dr. Hope........	Mr. Johnston, Dr. Christison.

SECTION B.—CHEMISTRY AND MINERALOGY.

1835. Dublin	Dr. T. Thomson, F.R.S.	Dr. Apjohn, Prof. Johnston.
1836. Bristol	Rev. Prof. Cumming..............	Dr. Apjohn, Dr. C. Henry, W. Herapath.
1837. Liverpool..	Michael Faraday, F.R.S.	Prof. Johnston, Prof. Miller, Dr. Reynolds.
1838. Newcastle...	Rev. William Whewell, F.R.S....	Prof. Miller, R. L. Pattinson, Thomas Richardson.
1839. Birmingham	Prof. T. Graham, F.R.S.	Golding Bird, M.D., Dr. J. B. Melson.
1840. Glasgow ..	Dr. Thomas Thomson, F.R.S. ...	Dr. R. D. Thomson, Dr. T. Clark, Dr. L. Playfair.
1841. Plymouth..	Dr. Daubeny, F.R.S.	J. Prideaux, Robert Hunt, W. M. Tweedy.
1842. Manchester.	John Dalton, D.C.L, F.R.S.......	Dr. L. Playfair, R. Hunt, J. Graham.

Date and Place.	Presidents.	Secretaries.
1843. Cork	Prof. Apjohn, M.R.I.A.	R. Hunt, Dr. Sweeny.
1844. York	Prof. T. Graham, F.R.S.	Dr. R. Playfair, E. Solly, T. H. Barker.
1845. Cambridge	Rev. Prof. Cumming	R. Hunt, J. P. Joule, Prof. Miller, E. Solly.
1846. Southampton	Michael Faraday, D.C.L., F.R.S.	Dr. Miller, R. Hunt, W. Randall.
1847. Oxford	Rev. W. V. Harcourt, M.A., F.R.S.	B. C. Brodie, R. Hunt, Prof. Solly.
1848. Swansea	Richard Phillips, F.R.S.	T. H. Henry, R. Hunt, T. Williams.
1849. Birmingham	John Percy, M.D., F.R.S.	R. Hunt, G. Shaw.
1850. Edinburgh	Dr. Christison, V.P.R.S.E.	Dr. Anderson, R. Hunt, Dr. Wilson.
1851. Ipswich	Prof. Thomas Graham, F.R.S.	T. J. Pearsall, W. S. Ward.
1852. Belfast	Thomas Andrews, M.D., F.R.S.	Dr. Gladstone, Prof. Hodges, Prof. Ronalds.
1853. Hull	Prof. J. F. W. Johnston, M.A., F.R.S.	H. S. Blundell, Prof. R. Hunt, T. J. Pearsall.
1854. Liverpool	Prof. W. A. Miller, M.D., F.R.S.	Dr. Edwards, Dr. Gladstone, Dr. Price.
1855. Glasgow	Dr. Lyon Playfair, C.B., F.R.S.	Prof. Frankland, Dr. H. E. Roscoe.
1856. Cheltenham	Prof. B. C. Brodie, F.R.S.	J. Horsley, P. J. Worsley, Prof. Voelcker.
1857. Dublin	Prof. Apjohn, M.D., F.R.S., M.R.I.A.	Dr. Davy, Dr. Gladstone, Prof. Sullivan.
1858. Leeds	Sir J. F. W. Herschel, Bart., D.C.L.	Dr. Gladstone, W. Odling, R. Reynolds.
1859. Aberdeen	Dr. Lyon Playfair, C.B., F.R.S.	J. S. Brazier, Dr. Gladstone, G. D. Liveing, Dr. Odling.
1860. Oxford	Prof. B. C. Brodie, F.R.S.	A. Vernon Harcourt, G. D. Liveing, A. B. Northcote.
1861. Manchester	Prof. W. A. Miller, M.D., F.R.S.	A. Vernon Harcourt, G. D. Liveing.
1862. Cambridge	Prof. W. A. Miller, M.D., F.R.S.	H. W. Elphinstone, W. Odling, Prof. Roscoe.
1863. Newcastle	Dr. Alex. W. Williamson, F.R.S.	Prof. Liveing, H. L. Pattinson, J. C. Stevenson.
1864. Bath	W. Odling, M.B., F.R.S., F.C.S.	A. V. Harcourt, Prof. Liveing, R. Biggs.
1865. Birmingham	Prof. W. A. Miller, M.D., V.P.R.S.	A. V. Harcourt, H. Adkins, Prof. Wanklyn, A. Winkler Wills.
1866. Nottingham	H. Bence Jones, M.D., F.R.S.	J. H. Atherton, Prof. Liveing, W. J. Russell, J. White.
1867. Dundee	Prof. T. Anderson, M.D., F.R.S.E.	A. Crum Brown, Prof. G. D. Liveing, W. J. Russell.
1868. Norwich	Prof. E. Frankland, F.R.S., F.C.S.	Dr. A. Crum Brown, Dr. W. J. Russell, F. Sutton.
1869. Exeter	Dr. H. Debus, F.R.S., F.C.S.	Prof. A. Crum Brown, M.D., Dr. W. J. Russell, Dr. Atkinson.
1870. Liverpool	Prof. H. E. Roscoe, B.A., F.R.S., F.C.S.	Prof. A. Crum Brown, M.D., A. E. Fletcher, Dr. W. J. Russell.
1871. Edinburgh	Prof. T. Andrews, M.D., F.R.S.	J. T. Buchanan, W. N. Hartley, T. E. Thorpe.
1872. Brighton	Dr. J. H. Gladstone, F.R.S.	Dr. Mills, W. Chandler Roberts, Dr. W. J. Russell, Dr. T. Wood.
1873. Bradford	Prof. W. J. Russell, F.R.S.	Dr. Armstrong, Dr. Mills, W. Chandler Roberts, Dr. Thorpe.
1874. Belfast	Prof. A. Crum-Brown, M.D., F.R.S.E., F.C.S.	Dr. T. Cranstoun Charles, W. Chandler Roberts, Prof. Thorpe.
1875. Bristol	A. G. Vernon Harcourt, M.A., F.R.S., F.C.S.	Dr. H. E. Armstrong, W. Chandler Roberts, W. A. Tilden.

GEOLOGICAL (AND, UNTIL 1851, GEOGRAPHICAL) SCIENCE.

COMMITTEE OF SCIENCES, III.—GEOLOGY AND GEOGRAPHY.

1832. Oxford	R. I. Murchison, F.R.S.	John Taylor.
1833. Cambridge	G. B. Greenough, F.R.S.	W. Lonsdale, John Phillips.
1834. Edinburgh	Prof. Jameson	Prof. Phillips, T. Jameson Torrie, Rev. J. Yates.

Date and Place.	Presidents.	Secretaries.
	SECTION C.—GEOLOGY AND GEOGRAPHY.	
1835. Dublin	R. J. Griffith	Captain Portlock, T. J. Torrie.
1836. Bristol	Rev. Dr. Buckland, F.R.S.—*Geography.* R. I. Murchison, F.R.S.	William Sanders, S. Stutchbury, T. J. Torrie.
1837. Liverpool	Rev. Prof. Sedgwick, F.R.S.—*Geography.* G. B. Greenough, F.R.S.	Captain Portlock, R. Hunter.—*Geography.* Captain H M. Denham, R.N.
1838. Newcastle	C. Lyell, F.R.S., V.P.G.S.—*Geography.* Lord Prudhope.	W. C. Trevelyan, Capt. Portlock.—*Geography.* Capt. Washington.
1839. Birmingham	Rev. Dr. Buckland, F.R.S.—*Geography.* G. B. Greenough, F.R.S.	George Lloyd, M.D., H. E. Strickland, Charles Darwin.
1840. Glasgow	Charles Lyell, F.R.S.—*Geography.* G. B. Greenough, F.R.S.	W. J. Hamilton, D. Milne, Hugh Murray, H. E. Strickland, John Scoular, M.D.
1841. Plymouth	H. T. De la Beche, F.R.S.	W. J. Hamilton, Edward Moore, M.D., R. Hutton.
1842. Manchester	R. I. Murchison, F.R.S.	E. W. Binney, R. Hutton, Dr. R. Lloyd, H. E. Strickland.
1843. Cork	Richard E. Griffith, F.R.S., M.R.I.A.	Francis M. Jennings, H. E. Strickland.
1844. York	Henry Warburton, M.P., Pres. Geol. Soc.	Prof. Ansted, E. H. Bunbury.
1845. Cambridge	Rev. Prof. Sedgwick, M.A., F.R.S.	Rev. J. C. Cumming, A. C. Ramsay, Rev. W. Thorp.
1846. Southampton	Leonard Horner, F.R.S.—*Geography.* G. B. Greenough, F.R.S.	Robert A. Austen, J. H. Norten, M.D., Prof. Oldham.—*Geography.* Dr. C. T. Beke.
1847. Oxford	Very Rev. Dr. Buckland, F.R.S.	Prof. Ansted, Prof. Oldham, A. C. Ramsay, J. Ruskin.
1848. Swansea	Sir H. T. De la Beche, C.B., F.R.S.	Starling Benson, Prof. Oldham, Prof. Ramsay.
1849. Birmingham	Sir Charles Lyell, F.R.S., F.G.S.	J. Beete Jukes, Prof. Oldham, Prof. A. C. Ramsay.
1850. Edinburgh *	Sir Roderick I. Murchison, F.R.S.	A. Keith Johnston, Hugh Miller, Professor Nicol.
	SECTION C (*continued*).—GEOLOGY.	
1851. Ipswich	William Hopkins, M.A., F.R.S.	C. J. F. Bunbury, G. W. Ormerod, Searles Wood.
1852. Belfast	Lieut.-Col. Portlock, R.E., F.R.S.	James Bryce, James MacAdam, Prof. M'Coy, Prof. Nicol.
1853. Hull	Prof. Sedgwick, F.R.S.	Prof. Harkness, William Lawton.
1854. Liverpool	Prof. Edward Forbes, F.R.S.	John Cunningham, Prof. Harkness, G. W. Ormerod, J. W. Woodall.
1855. Glasgow	Sir R. I. Murchison, F.R.S.	James Bryce, Prof. Harkness, Prof. Nicol.
1856. Cheltenham	Prof. A. C. Ramsay, F.R.S.	Rev. P. B. Brodie, Rev. R. Hepworth, Edward Hull, J. Scougall, T. Wright.
1857. Dublin	The Lord Talbot de Malahide	Prof. Harkness, Gilbert Sanders, Robert H. Scott.
1858. Leeds	William Hopkins, M.A., LL.D., F.R.S.	Prof. Nicol, H. C. Sorby, E. W. Shaw.
1859. Aberdeen	Sir Charles Lyell, LL.D., D.C.L., F.R.S.	Prof. Harkness, Rev. J. Longmuir, H. C. Sorby.
1860. Oxford	Rev. Prof. Sedgwick, LL.D., F.R.S., F.G.S.	Prof. Harkness, Edward Hull, Capt. Woodall.

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* At a Meeting of the General Committee held in 1850, it was resolved "That the subject of Geography be separated from Geology and combined with Ethnology, to constitute a separate Section, under the title of the "Geographical and Ethnological Section," for Presidents and Secretaries of which see page xxxvii.

Date and Place.	Presidents.	Secretaries.
1861. Manchester	Sir R. I. Murchison, D.C.L., LL.D., F.R.S., &c.	Prof. Harkness, Edward Hull, T. Rupert Jones, G. W. Ormerod.
1862. Cambridge	J. Beete Jukes, M.A., F.R.S.	Lucas Barrett, Prof. T. Rupert Jones, H. C. Sorby.
1863. Newcastle	Prof. Warington W. Smyth, F.R.S., F.G.S.	E. F. Boyd, John Daglish, H. C. Sorby, Thomas Sopwith.
1864. Bath	Prof. J. Phillips, LL.D., F.R.S., F.G.S.	W. B. Dawkins, J. Johnston, H. C. Sorby, W. Pengelly.
1865. Birmingham	Sir R. I. Murchison, Bart., K.C.B.	Rev. P. B. Brodie, J. Jones, Rev. E. Myers, H. C. Sorby, W. Pengelly.
1866. Nottingham	Prof. A. C. Ramsay, LL.D., F.R.S.	R. Etheridge, W. Pengelly, T. Wilson, G. H. Wright.
1867. Dundee	Archibald Geikie, F.R.S., F.G.S.	Edward Hull, W. Pengelly, Henry Woodward.
1868. Norwich	R. A. C. Godwin-Austen, F.R.S., F.G.S.	Rev. O. Fisher, Rev. J. Gunn, W. Pengelly, Rev. H. H. Winwood.
1869. Exeter	Prof. R. Harkness, F.R.S., F.G.S.	W. Pengelly, W. Boyd Dawkins, Rev. H. H. Winwood.
1870. Liverpool	Sir Philip de M. Grey Egerton, Bart., M.P., F.R.S.	W. Pengelly, Rev. H. H. Winwood, W. Boyd Dawkins, G. H. Morton.
1871. Edinburgh	Prof. A. Geikie, F.R.S., F.G.S.	R. Etheridge, J. Geikie, J. McKenny Hughes, L. C. Miall.
1872. Brighton	R. A. C. Godwin-Austen, F.R.S.	L. C. Miall, George Scott, William Topley, Henry Woodward.
1873. Bradford	Prof. J. Phillips, D.C.L., F.R.S., F.G.S.	L. C. Miall, R. H. Tiddeman, W. Topley.
1874. Belfast	Prof. Hull, M.A., F.R.S., F.G.S.	F. Drew, L. C. Miall, R. G. Symes, R. H. Tiddeman.
1875. Bristol	Dr. Thomas Wright, F.R.S.E., F.G.S.	L. C. Miall, E. B. Tawney, W. Topley.

BIOLOGICAL SCIENCES.

COMMITTEE OF SCIENCES, IV.—ZOOLOGY, BOTANY, PHYSIOLOGY, ANATOMY.

1832. Oxford	Rev. P. B. Duncan, F.G.S.	Rev. Prof. J. S. Henslow.
1833. Cambridge*	Rev. W. L. P. Garnons, F.L.S.	C. C. Babington, D. Don.
1834. Edinburgh	Prof. Graham	W. Yarrell, Prof. Burnett.

SECTION D.—ZOOLOGY AND BOTANY.

1835. Dublin	Dr. Allman	J. Curtis, Dr. Litton.
1836. Bristol	Rev. Prof. Henslow	J. Curtis, Prof. Don, Dr. Riley, S. Rootsey.
1837. Liverpool	W. S. MacLeay	C. C. Babington, Rev. L. Jenyns, W. Swainson.
1838. Newcastle	Sir W. Jardine, Bart.	J. E. Gray, Prof. Jones, R. Owen, Dr. Richardson.
1839. Brimingham	Prof. Owen, F.R.S.	E. Forbes, W. Ick, R. Patterson.
1840. Glasgow	Sir W. J. Hooker, LL.D	Prof. W. Couper, E. Forbes, R. Patterson.
1841. Plymouth	John Richardson, M.D., F.R.S.	J. Couch, Dr. Lankester, R. Patterson.
1842. Manchester	Hon. and Very Rev. W. Herbert, LL.D., F.L.S.	Dr. Lankester, R. Patterson, J. A. Turner.
1843. Cork	William Thompson, F.L.S.	G. J. Allman, Dr. Lankester, R. Patterson.
1844. York	Very Rev. The Dean of Manchester.	Prof. Allman, H. Goodsir, Dr. King, Dr. Lankester.
1845. Cambridge	Rev. Prof. Henslow, F.L.S.	Dr. Lankester, T. V. Wollaston.
1846. Southampton	Sir J. Richardson, M.D., F.R.S.	Dr. Lankester, T. V. Wollaston, H. Wooldridge.
1847. Oxford	H. E. Strickland, M.A., F.R.S.	Dr. Lankester, Dr. Melville, T. V. Wollaston.

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* At this Meeting Physiology and Anatomy were made a separate Committee, for Presidents and Secretaries of which see xxxp. vi.

SECTION D (*continued*).—ZOOLOGY AND BOTANY, INCLUDING PHYSIOLOGY.

[For the Presidents and Secretaries of the Anatomical and Physiological Subsections and the temporary Section E of Anatomy and Medicine, see p. xxxvi.]

Date and Place.	Presidents.	Secretaries.
1848. Swansea ...	L. W. Dillwyn, F.R.S.	Dr. R. Wilbraham Falconer, A. Henfrey, Dr. Lankester.
1849. Birmingham	William Spence, F.R.S..............	Dr. Lankester, Dr. Russell.
1850. Edinburgh..	Prof. Goodsir, F.R.S. L. & E....	Prof. J. H. Bennett, M.D., Dr. Lankester, Dr. Douglas Maclagan.
1851. Ipswich......	Rev. Prof. Henslow, M.A., F.R.S.	Prof. Allman, F. W. Johnston, Dr. E. Lankester.
1852. Belfast	W. Ogilby	Dr. Dickie, George C. Hyndman, Dr. Edwin Lankester.
1853. Hull	C. C. Babington, M.A., F.R.S....	Robert Harrison, Dr. E. Lankester.
1854. Liverpool ...	Prof. Balfour, M.D., F.R.S.......	Isaac Byerley, Dr. E. Lankester.
1855. Glasgow ...	Rev. Dr. Fleeming, F.R.S.E. ...	William Keddie, Dr. Lankester.
1856. Cheltenham.	Thomas Bell, F.R.S., Pres.L.S....	Dr. J. Abercrombie, Prof. Buckman Dr. Lankester.
1857. Dublin	Prof. W. H. Harvey, M.D., F.R.S.	Prof. J. R. Kinahan, Dr. E. Lankester, Robert Patterson, Dr. W. E. Steele.
1858. Leeds.........	C. C. Babington, M.A., F.R.S....	Henry Denny, Dr. Heaton, Dr. E. Lankester, Dr. E. Perceval Wright.
1859. Aberdeen ...	Sir W. Jardine, Bart., F.R.S.E..	Prof. Dickie, M.D., Dr. E. Lankester, Dr. Ogilvy.
1860. Oxford	Rev. Prof. Henslow, F.L.S.	W. S. Church, Dr. E. Lankester, P. L. Sclater, Dr. E. Perceval Wright.
1861. Manchester..	Prof. C. C. Babington, F.R.S....	Dr. T. Alcock, Dr. E. Lankester, Dr. P. L. Sclater, Dr. E. P. Wright.
1862. Cambridge...	Prof. Huxley, F.R.S.	Alfred Newton, Dr. E. P. Wright.
1863. Newcastle ...	Prof. Balfour, M.D., F.R.S.	Dr. E. Charlton, A. Newton, Rev. H. B. Tristram, Dr. E. P. Wright.
1864. Bath	Dr. John E. Gray, F.R.S.	H. B. Brady, C. E. Broom, H. T. Stainton, Dr. E. P. Wright.
1865. Birmingham	T. Thomson, M.D., F.R.S.	Dr. J. Anthony, Rev. C. Clarke, Rev. H. B. Tristram, Dr. E. P. Wright.

SECTION D (*continued*).—BIOLOGY*.

1866. Nottingham.	Prof. Huxley, LL.D., F.R.S.—*Physiological Dep.* Prof. Humphry, M.D., F.R.S.—*Anthropological Dep.* Alfred R. Wallace, F.R.G.S.	Dr. J. Beddard, W. Felkin, Rev. H. B. Tristram, W. Turner, E. B. Tylor, Dr. E. P. Wright.
1867. Dundee......	Prof. Sharpey, M.D., Sec. R.S.—*Dep. of Zool. and Bot.* George Busk, M.D., F.R.S.	C. Spence Bate, Dr. S. Cobbold, Dr. M. Foster, H. T. Stainton, Rev. H. B. Tristram, Prof. W. Turner.
1868. Norwich ...	Rev. M. J. Berkeley, F.L.S.—*Dep. of Physiology.* W. H. Flower, F.R.S.	Dr. T. S. Cobbold, G. W. Firth, Dr. M. Foster, Prof. Lawson, H. T. Stainton, Rev. Dr. H. B. Tristram, Dr. E. P. Wright.
1869. Exeter	George Busk, F.R.S., F.L.S.—*Dep. of Bot. and Zool.* C. Spence Bate, F.R.S.—*Dep. of Ethno.* E. B. Tylor.	Dr. T. S. Cobbold, Prof. M. Foster, M.D., E. Ray Lankester, Professor Lawson, H. T. Stainton, Rev. H. B. Tristram.

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* At a Meeting of the General Committee in 1865, it was resolved:—"That the title of Section D be changed to Biology;" and "That for the word 'Subsection,' in the rules for conducting the business of the Sections, the word 'Department' be substituted."

Date and Place.	Presidents.	Secretaries.
1870. Liverpool...	Prof. G. Rolleston, M.A., M.D., F.R.S., F.L.S.—*Dep. Anat. and Physiol.* Prof. M. Foster, M.D., F.L.S.—*Dep. of Ethno.* J. Evans, F.R.S.	Dr. T. S. Cobbold, Sebastian Evans, Prof. Lawson, Thos. J. Moore, H. T. Stainton, Rev. H. B. Tristram, C. Staniland Wake, E. Ray Lankester.
1871. Edinburgh	Prof. Allen Thomson, M.D., F.R.S. —*Dep. of Bot. and Zool.* Prof. Wyville Thomson, F.R.S.—*Dep. of Anthropol.* Prof. W. Turner, M.D.	Dr. T. R. Fraser, Dr. Arthur Gamgee, E. Ray Lankester, Prof. Lawson, H. T. Stainton, C. Staniland Wake, Dr. W. Rutherford, Dr. Kelburne King.
1872. Brighton ...	Sir John Lubbock, Bart., F.R.S. —*Dep. of Anat. and Physiol.* Dr. Burdon Sanderson, F.R S. —*Dep of Anthropol.* Col. A. Lane Fox, F.G.S.	Prof. Thiselton-Dyer, H. T. Stainton, Prof. Lawson, F. W. Rudler, J. H. Lamprey, Dr. Gamgee, E. Ray Lankester, Dr. Pye-Smith.
1873. Bradford ...	Prof. Allman, F.R.S.—*Dep. of Anat. and Physiol.* Prof. Rutherford, M.D.—*Dep. of Anthropol.* Dr. Beddoe, F.R.S.	Prof. Thiselton-Dyer, Prof. Lawson, R. M'Lachlan, Dr. Pye-Smith, E. Ray Lankester, F. W. Rudler, J. H. Lamprey.
1874. Belfast......	Prof. Redfern, M.D.—*Dep. of Zool. and Bot.* Dr. Hooker, C B., Pres. R.S..—*Dep. of Anthropol.* Sir W. R. Wilde, M.D.	W. T. Thiselton-Dyer, R. O. Cunningham, Dr. J. J. Charles, Dr. P. H. Pye-Smith, J. J. Murphy, F. W. Rudler.
1875. Bristol......	P. L. Sclater, F.R.S.—*Dep. of Anat. and Physiol.* Prof. Cleland, M.D., F.R.S.—*Dep. of Anthropol.* Prof. Rolleston, M.D., F.R.S.	E. R. Alston, Dr. McKendrick, Prof. W. R. M'Nab, Dr. Martyn, F. W. Rudler, Dr. P. H. Pye-Smith, Dr. W. Spencer.

ANATOMICAL AND PHYSIOLOGICAL SCIENCES.

COMMITTEE OF SCIENCES, V.—ANATOMY AND PHYSIOLOGY.

1833. Cambridge...	Dr. Haviland	Dr. Bond, Mr. Paget.
1834. Edinburgh...	Dr. Abercrombie	Dr. Roget, Dr. William Thomson.

SECTION E. (UNTIL 1847.)—ANATOMY AND MEDICINE.

1835. Dublin	Dr. Pritchard	Dr. Harrison, Dr. Hart.
1836. Bristol	Dr. Roget, F.R.S.	Dr. Symonds.
1837. Liverpool ...	Prof. W. Clark, M.D.	Dr. J. Carson, jun., James Long, Dr. J. R. W. Vose.
1838. Newcastle ...	T. E. Headlam, M.D.	T. M. Greenhow, Dr. J. R. W. Vose.
1839. Birmingham	John Yelloly, M.D., F.R.S.	Dr. G. O. Rees, F. Ryland.
1840. Glasgow ...	James Watson, M.D................	Dr. J. Brown, Prof. Couper, Prof. Reid.
1841. Plymouth ...	P. M. Roget, M.D., Sec.R.S. ...	Dr. J. Butter, J. Fuge, Dr. R. S. Sargent.
1842. Manchester .	Edward Holme, M.D., F.L.S. ...	Dr. Chaytor, Dr. R. S. Sargent.
1843. Cork	Sir James Pitcairn, M.D.	Dr. John Popham, Dr. R. S. Sargent.
1844. York	J. C. Pritchard, M.D.	I. Erichsen, Dr. R. S. Sargent.

SECTION E.—PHYSIOLOGY.

1845. Cambridge .	Prof. J. Haviland, M.D.	Dr. R. S. Sargent, Dr. Webster.
1846. Southampton	Prof. Owen, M.D., F.R.S..........	C. P. Keele, Dr. Laycock, Dr. Sargent.
1847. Oxford* ...	Prof. Ogle, M.D., F.R.S.	Dr. Thomas K. Chambers, W. P. Ormerod.

PHYSIOLOGICAL SUBSECTIONS OF SECTION D.

1850. Edinburgh	Prof. Bennett, M.D., F.R.S.E.	
1855. Glasgow ...	Prof. Allen Thomson, F.R.S. ...	Prof. J. H. Corbett, Dr. J. Struthers.
1857. Dublin	Prof. R. Harrison, M.D.	Dr. R. D. Lyons, Prof. Redfern.

* By direction of the General Committee at Oxford, Sections D and E were incorporated under the name of "Section D—Zoology and Botany, including Physiology" (see p. xxxiv). The Section being then vacant was assigned in 1851 to Geography.

Date and Place.	Presidents.	Secretaries.
1858. Leeds	Sir Benjamin Brodie, Bart., F.R.S.	C. G. Wheelhouse.
1859. Aberdeen	Prof. Sharpey, M.D., Sec.R.S.	Prof. Bennett, Prof. Redfern.
1860. Oxford	Prof. G. Rolleston, M.D., F.L.S.	Dr. R. M'Donnell, Dr. Edward Smith.
1861. Manchester.	Dr. John Davy, F.R.S.L. & E.	Dr. W. Roberts, Dr. Edward Smith.
1862. Cambridge.	C. E. Paget, M.D.	G. F. Helm, Dr. Edward Smith.
1863. Newcastle	Prof. Rolleston, M.D., F.R.S.	Dr. D. Embleton, Dr. W. Turner.
1864. Bath	Dr. Edward Smith, LL.D., F.R.S.	J. S. Bartrum, Dr. W. Turner.
1865. Birminghm*.	Prof. Acland, M.D., LL.D., F.R.S.	Dr. A. Fleming, Dr. P. Heslop, Oliver Pembleton, Dr. W. Turner.

GEOGRAPHICAL AND ETHNOLOGICAL SCIENCES.

[For Presidents and Secretaries for Geography previous to 1851, see Section C, p. xxxii.]

ETHNOLOGICAL SUBSECTIONS OF SECTION D.

1846. Southampton	Dr. Pritchard	Dr. King.
1847. Oxford	Prof. H. H. Wilson, M.A.	Prof. Buckley.
1848. Swansea		G. Grant Francis.
1849. Birmingham		Dr. R. G. Latham.
1850. Edinburgh.	Vice-Admiral Sir A. Malcolm	Daniel Wilson.

SECTION E.—GEOGRAPHY AND ETHNOLOGY.

1851. Ipswich	Sir R. I. Murchison, F.R.S., Pres. R.G.S.	R. Cull, Rev. J. W. Donaldson, Dr. Norton Shaw.
1852. Belfast	Col. Chesney, R.A., D.C.L., F.R.S.	R. Cull, R. MacAdam, Dr. Norton Shaw.
1853. Hull	R. G. Latham, M.D., F.R.S.	R. Cull, Rev. H. W. Kemp, Dr. Norton Shaw.
1854. Liverpool	Sir R. I. Murchison, D.C.L., F.R.S.	Richard Cull, Rev. H. Higgins, Dr. Ihne, Dr. Norton Shaw.
1855. Glasgow	Sir J. Richardson, M.D., F.R.S.	Dr. W. G. Blackie, R. Cull, Dr. Norton Shaw.
1856. Cheltenham	Col. Sir H. C. Rawlinson, K.C.B.	R. Cull, F. D. Hartland, W. H. Rumsey, Dr. Norton Shaw.
1857. Dublin	Rev. Dr. J. Henthawn Todd, Pres. R.I.A.	R. Cull, S. Ferguson, Dr. R. R. Madden, Dr. Norton Shaw.
1858. Leeds	Sir R. I. Murchison, G.C.St.S., F.R.S.	R. Cull, Francis Galton, P. O'Callaghan, Dr. Norton Shaw, Thomas Wright.
1859. Aberdeen	Rear-Admiral Sir James Clerk Ross, D.C.L., F.R.S.	Richard Cull, Professor Geddes, Dr. Norton Shaw.
1860. Oxford	Sir R. I. Murchison, D.C.L., F.R.S.	Capt. Burrows, Dr. J. Hunt, Dr. C. Lempriere, Dr. Norton Shaw.
1861. Manchester.	John Crawfurd, F.R.S.	Dr. J. Hunt, J. Kingsley, Dr. Norton Shaw, W. Spottiswoode.
1862. Cambridge.	Francis Galton, F.R.S.	J. W. Clarke, Rev. J. Glover, Dr. Hunt, Dr. Norton Shaw, T. Wright.
1863. Newcastle	Sir R. I. Murchison, K.C.B., F.R.S.	C. Carter Blake, Hume Greenfield, C. R. Markham, R. S. Watson.
1864. Bath	Sir R. I. Murchison, K.C.B., F.R.S.	H. W. Bates, C. R. Markham, Capt. R. M. Murchison, T. Wright.
1865. Birmingham	Major-General Sir H. Rawlinson, M.P., K.C.B., F.R.S.	H. W. Bates, S. Evans, G. Jabet, C. R. Markham, Thomas Wright.
1866. Nottingham	Sir Charles Nicholson, Bart., LL.D.	H. W. Bates, Rev. E. T. Cusins, R. H. Major, Clements R. Markham, D. W. Nash, T. Wright.
1867. Dundee	Sir Samuel Baker, F.R.G.S.	H. W. Bates, Cyril Graham, C. R. Markham, S. J. Mackie, R. Sturrock.
1868. Norwich	Capt. G. H. Richards, R.N., F.R.S.	T. Baines, H. W. Bates, C. R. Markham, T. Wright.

* *Vide* note on page xxxv.

SECTION E (*continued*).—GEOGRAPHY.

Date and Place.	Presidents.	Secretaries.
1869. Exeter	Sir Bartle Frere, K.C.B., LL.D., F.R.G.S.	H. W. Bates, Clements R. Markham, J. H. Thomas.
1870. Liverpool	Sir R. I. Murchison, Bt., K.C.B., LL.D., D.C.L., F.R.S., F.G.S.	H. W. Bates, David Buxton, Albert J. Mott, Clements R. Markham.
1871. Edinburgh.	Colonel Yule, C.B., F.R.G.S.	Clements R. Markham, A. Buchan, J. H. Thomas, A. Keith Johnston.
1872. Brighton	Francis Galton, F.R.S.	H. W. Bates, A. Keith Johnston, Rev. J. Newton, J. H. Thomas.
1873. Bradford	Sir Rutherford Alcock, K.C.B.	H. W. Bates, A. Keith Johnston, Clements R. Markham.
1874. Belfast	Major Wilson, R.E., F.R.S., F.R.G.S.	E. G. Ravenstein, E. C. Rye, J. H. Thomas.
1875. Bristol	Lieut.-General Strachey, R.E., C.S.I., F.R.S., F.R.G.S., F.L.S., F.G.S.	H. W. Bates, E. C. Rye, F. F. Tuckett.

STATISTICAL SCIENCE.

COMMITTEE OF SCIENCES, VI.—STATISTICS.

1833. Cambridge	Prof. Babbage, F.R.S.	J. E. Drinkwater.
1834. Edinburgh	Sir Charles Lemon, Bart.	Dr. Cleland, C. Hope Maclean.

SECTION F.—STATISTICS

1835. Dublin	Charles Babbage, F.R.S.	W. Greg, Prof. Longfield.
1836. Bristol	Sir Charles Lemon, Bart., F.R.S.	Rev. J. E. Bromby, C. B. Fripp, James Heywood.
1837. Liverpool	Rt. Hon. Lord Sandon	W. R. Greg, W. Langton, Dr. W. C. Tayler.
1838. Newcastle	Colonel Sykes, F.R.S.	W. Cargill, J. Heywood, W. R. Wood.
1839. Birmingham	Henry Hallam, F.R.S.	F. Clarke, R. W. Rawson, Dr. W. C. Tayler.
1840. Glasgow	Rt. Hon. Lord Sandon, M.P., F.R.S.	C. R. Baird, Prof. Ramsay, R. W. Rawson.
1841. Plymouth	Lieut.-Col. Sykes, F.R.S.	Rev. Dr. Byrth, Rev. R. Luney, R. W. Rawson.
1842. Manchester.	G. W. Wood, M.P., F.L.S.	Rev. R. Luney, G. W. Ormerod, Dr. W. C. Tayler.
1843. Cork	Sir C. Lemon, Bart., M.P.	Dr. D. Bullen, Dr. W. Cooke Tayler.
1844. York	Lieut.-Col. Sykes, F.R.S., F.L.S.	J. Fletcher, J. Heywood, Dr. Laycock.
1845. Cambridge	Rt. Hon. The Earl Fitzwilliam	J. Fletcher, W. Cooke Tayler, LL.D.
1846. Southampton	G. R. Porter, F.R.S.	J. Fletcher, F. G. P. Neison, Dr. W. C. Tayler, Rev. T. L. Shapcott.
1847. Oxford	Travers Twiss, D.C.L., F.R.S.	Rev. W. H. Cox, J. J. Danson, F. G. P. Neison.
1848. Swansea	J. H. Vivian, M.P., F.R.S.	J. Fletcher, Capt. R. Shortrede.
1849. Birmingham	Rt. Hon. Lord Lyttelton	Dr. Finch, Prof. Hancock, F. G. P. Neison.
1850. Edinburgh	Very Rev. Dr. John Lee, V.P.R.S.E.	Prof. Hancock, J. Fletcher, Dr. J. Stark.
1851. Ipswich	Sir John P. Boileau, Bart.	J. Fletcher, Prof. Hancock.
1852. Belfast	His Grace the Archbishop of Dublin.	Prof. Hancock, Prof. Ingram, James MacAdam, Jun.
1853. Hull	James Heywood, M.P., F.R.S.	Edward Cheshire, William Newmarch.
1854. Liverpool	Thomas Tooke, F.R.S.	E. Cheshire, J. T. Danson, Dr. W. H. Duncan, W. Newmarch.
1855. Glasgow	R. Monckton Milnes, M.P.	J. A. Campbell, E. Cheshire, W. Newmarch, Prof. R. H. Walsh.

SECTION F (*continued*).—ECONOMIC SCIENCE AND STATISTICS.

1856. Cheltenham	Rt. Hon. Lord Stanley, M.P.	Rev. C. H. Bromby, E. Cheshire, Dr. W. N. Hancock Newmarch, W. M. Tartt.

Date and Place.	Presidents.	Secretaries.
1857. Dublin	His Grace the Archbishop of Dublin, M.R.I.A.	Prof. Cairns, Dr. H. D. Hutton, W. Newmarch.
1858. Leeds	Edward Baines	T. B. Baines, Prof. Cairns, S. Brown, Capt. Fishbourne, Dr. J. Strang.
1859. Aberdeen	Col. Sykes, M.P., F.R.S.	Prof. Cairns, Edmund Macrory, A. M. Smith, Dr. John Strang.
1860. Oxford	Nassau W. Senior, M.A.	Edmund Macrory, W. Newmarch, Rev. Prof. J. E. T. Rogers.
1861. Manchester	William Newmarch, F.R.S.	David Chadwick, Prof. R. C. Christie, E. Macrory, Rev. Prof. J. E. T. Rogers.
1862. Cambridge	Edwin Chadwick, C.B.	H. D. Macleod, Edmund Macrory.
1863. Newcastle	William Tite, M.P., F.R.S.	T. Doubleday, Edmund Macrory, Frederick Purdy, James Potts.
1864. Bath	William Farr, M.D., D.C.L., F.R.S.	E. Macrory, E. T. Payne, F. Purdy.
1865. Birmingham	Rt. Hon. Lord Stanley, LL.D., M.P.	G. J. D. Goodman, G. J. Johnston, E. Macrory.
1866. Nottingham	Prof. J. E. T. Rogers	R. Birkin, Jun., Prof. Leone Levi, E. Macrory.
1867. Dundee	M. E. Grant Duff, M.P.	Prof. Leone Levi, E. Macrory, A. J. Warden.
1868. Norwich	Samuel Brown, Pres. Instit. Actuaries.	Rev. W. C. Davie, Prof. Leone Levi.
1869. Exeter	Rt. Hon. Sir Stafford H. Northcote, Bart., C.B., M.P.	Edmund Macrory, Frederick Purdy, Charles T. D. Acland.
1870. Liverpool	Prof. W. Stanley Jevons, M.A.	Chas. R. Dudley Baxter, E. Macrory, J. Miles Moss.
1871. Edinburgh	Rt. Hon. Lord Neaves	J. G. Fitch, James Meikle.
1872. Brighton	Prof. Henry Fawcett, M.P.	J. G. Fitch, Barclay Phillips.
1873. Bradford	Rt. Hon. W. E. Forster, M.P.	J. G. Fitch, Swire Smith.
1874. Belfast	Lord O'Hagan.	Prof. Donnell, Frank P. Fellows, Hans MacMordie.
1875. Bristol	James Heywood, M.A., F.R.S., Pres.S.S.	F. P. Fellows, T. G. P. Hallett, E. Macrory.

MECHANICAL SCIENCE.

SECTION G.—MECHANICAL SCIENCE.

1836. Bristol	Davies Gilbert, D.C.L., F.R.S.	T. G. Bunt, G. T. Clark, W. West.
1837. Liverpool	Rev. Dr. Robinson	Charles Vignoles, Thomas Webster.
1838. Newcastle	Charles Babbage, F.R.S.	R. Hawthorn, C. Vignoles, T. Webster.
1839. Birmingham	Prof. Willis, F.R.S., and Robert Stephenson.	W. Carpmael, William Hawkes, Thomas Webster.
1840. Glasgow	Sir John Robinson	J. Scott Russell, J. Thomson, J. Tod, C. Vignoles.
1841. Plymouth	John Taylor, F.R.S.	Henry Chatfield, Thomas Webster.
1842. Manchester	Rev. Prof. Willis, F.R.S.	J. F. Bateman, J. Scott Russell, J. Thomson, Charles Vignoles.
1843. Cork	Prof. J. Macneill, M.R.I.A.	James Thomson, Robert Mallet.
1844. York	John Taylor, F.R.S.	Charles Vignoles, Thomas Webster.
1845. Cambridge	George Rennie, F.R.S.	Rev. W. T. Kingsley.
1846. Southampton	Rev. Prof. Willis, M.A., F.R.S.	William Betts, Jun., Charles Manby.
1847. Oxford	Rev. Prof. Walker, M.A., F.R.S.	J. Glynn, R. A. Le Mesurier.
1848. Swansea	Rev. Prof. Walker, M.A., F.R.S.	R. A. Le Mesurier, W. P. Struvé.
1849. Birmingham	Robert Stephenson, M.P., F.R.S.	Charles Manby, W. P. Marshall.
1850. Edinburgh	Rev. Dr. Robinson	Dr. Lees, David Stephenson.
1851. Ipswich	William Cubitt, F.R.S.	John Head, Charles Manby.
1852. Belfast	John Walker, C.E., LL.D., F.R.S.	John F. Bateman, C. B. Hancock, Charles Manby, James Thomson.
1853. Hull	William Fairbairn, C.E., F.R.S.	James Oldham, J. Thomson, W. Sykes Ward.

Date and Place.	Presidents.	Secretaries.
1854. Liverpool ...	John Scott Russell, F.R.S.	John Grantham, J. Oldham, J. Thomson.
1855. Glasgow ...	W. J. Macquorn Rankine, C.E., F.R.S.	L. Hill, Jun., William Ramsay, J. Thomson.
1856. Cheltenham	George Rennie, F.R.S.	C. Atherton, B. Jones, Jun., H. M. Jeffery.
1857. Dublin	The Right Hon. The Earl of Rosse, F.R.S.	Prof. Downing, W. T. Doyne, A. Tate James Thomson, Henry Wright.
1858. Leeds.........	William Fairbairn, F.R.S.	J. C. Dennis, J. Dixon, H. Wright.
1859. Aberdeen ...	Rev. Prof. Willis, M.A., F.R.S. .	R. Abernethy, P. Le Neve Foster, H Wright.
1860. Oxford	Prof. W. J. Macquorn Rankine, LL.D., F.R.S.	P. Le Neve Foster, Rev. F. Harrison, Henry Wright.
1861. Manchester .	J. F. Bateman, C.E., F.R.S.......	P. Le Neve Foster, John Robinson, H. Wright.
1862. Cambridge ..	William Fairbairn, LL.D., F.R.S.	W. M. Fawcett, P. Le Neve Foster.
1863. Newcastle ...	Rev. Prof. Willis, M.A., F.R.S. .	P. Le Neve Foster, P. Westmacott, J. F. Spencer.
1864. Bath	J. Hawkshaw, F.R.S.	P. Le Neve Foster, Robert Pitt.
1865. Birmingham	Sir W. G. Armstrong, LL.D., F.R.S.	P. Le Neve Foster, Henry Lea, W. P. Marshall, Walter May.
1866. Nottingham	Thomas Hawksley, V.P.Inst. C.E., F.G.S.	P. Le Neve Foster, J. F. Iselin, M. A. Tarbottom.
1867. Dundee......	Prof. W. J. Macquorn Rankine, LL.D., F.R.S.	P. Le Neve Foster, John P. Smith, W. W. Urquhart.
1868. Norwich ...	G. P. Bidder, C.E., F.R.G.S. ...	P. Le Neve Foster, J. F. Iselin, C. Manby, W. Smith.
1869. Exeter	C. W. Siemens, F.R.S.	P. Le Neve Foster, H. Bauerman.
1870. Liverpool ...	Chas. B. Vignoles, C.E., F.R.S. .	H. Bauerman, P. Le Neve Foster, T. King, J. N. Shoolbred.
1871. Edinburgh	Prof. Fleeming Jenkin, F.R.S....	H. Bauerman, Alexander Leslie, J. P. Smith.
1872. Brighton ...	F. J. Bramwell, C.E................	H. M. Brunel, P. Le Neve Foster, J. G. Gamble, J. N. Shoolbred.
1873. Bradford ...	W. H. Barlow, F.R.S.	Crawford Barlow, H. Bauerman, S. H. Carbutt, J. C. Hawkshaw, J. N. Shoolbred.
1874. Belfast	Prof. James Thomson, LL.D., C.E., F.R.S.E.	A. T. Atchison, J. N. Shoolbred, John Smyth, jun.
1875. Bristol	W. Froude, C.E., M.A., F.R.S....	W. R. Browne, H. M. Brunel, J. G. Gamble, J. N. Shoolbred.

List of Evening Lectures.

Date and Place.	Lecturer.	Subject of Discourse.
1842. Manchester .	Charles Vignoles, F.R.S..........	The Principles and Construction of Atmospheric Railways.
	Sir M. I. Brunel	The Thames Tunnel.
	R. I. Murchison...................	The Geology of Russia.
1843. Cork	Prof. Owen, M.D., F.R.S.	The Dinornis of New Zealand.
	Prof. E. Forbes, F.R.S.	The Distribution of Animal Life in the Ægean Sea.
	Dr. Robinson	The Earl of Rosse's Telescope.
1844. York	Charles Lyell, F.R.S.	Geology of North America.
	Dr. Falconer, F.R.S.	The Gigantic Tortoise of the Siwalik Hills in India.

Date and Place.	Lecturer.	Subject of Discourse.
1845. Cambridge..	G. B. Airy, F.R.S., Astron. Royal	Progress of Terrestrial Magnetism.
	R. I. Murchison, F.R.S.	Geology of Russia.
1846. Southampton	Prof. Owen, M.D., F.R.S.	Fossil Mammalia of the British Isles.
	Charles Lyell, F.R.S.	Valley and Delta of the Mississippi.
1846. Southampton	W. R. Grove, F.R.S.	Properties of the Explosive substance discovered by Dr. Schönbein; also some Researches of his own on the Decomposition of Water by Heat.
1847. Oxford	Rev. Prof. B. Powell, F.R.S. ...	Shooting-stars.
	Prof. M. Faraday, F.R.S.	Magnetic and Diamagnetic Phenomena.
	Hugh E. Strickland, F.G.S. ...	The Dodo (*Didus ineptus*).
1848. Swansea ...	John Percy, M.D., F.R.S.	Metallurgical operations of Swansea and its neighbourhood.
	W. Carpenter, M.D., F.R.S. ...	Recent Microscopical Discoveries.
1849. Birmingham	Dr. Faraday, F.R.S.	Mr. Gassiot's Battery.
	Rev. Prof. Willis, M.A., F.R.S.	Transit of different Weights with varying velocities on Railways.
1850. Edinburgh.	Prof. J. H. Bennett, M.D., F.R.S.E.	Passage of the Blood through the minute vessels of Animals in connexion with Nutrition.
	Dr. Mantell, F.R.S.	Extinct Birds of New Zealand.
1851. Ipswich	Prof. R. Owen, M.D., F.R.S.	Distinction between Plants and Animals, and their changes of Form.
	G. B. Airy, F.R.S., Astron. Royal	Total Solar Eclipse of July 28, 1851.
1852. Belfast	Prof. G. G. Stokes, D.C.L., F.R.S.	Recent discoveries in the properties of Light.
	Colonel Portlock, R.E., F.R.S.	Recent discovery of Rock-salt at Carrickfergus, and geological and practical considerations connected with it.
1853. Hull	Prof. J. Phillips, LL.D., F.R.S., F.G S.	Some peculiar phenomena in the Geology and Physical Geography of Yorkshire.
	Robert Hunt, F.R.S.	The present state of Photography.
1854. Liverpool ...	Prof. R. Owen, M.D., F.R.S. ...	Anthropomorphous Apes.
	Col. E. Sabine, V.P.R.S.	Progress of researches in Terrestrial Magnetism.
1855. Glasgow......	Dr. W. B. Carpenter, F.R.S. ...	Characters of Species.
	Lieut.-Col. H. Rawlinson	Assyrian and Babylonian Antiquities and Ethnology.
1856. Cheltenham	Col. Sir H. Rawlinson	Recent discoveries in Assyria and Babylonia, with the results of Cuneiform research up to the present time.
	W. R. Grove, F.R.S.	Correlation of Physical Forces.
1857. Dublin	Prof. W. Thomson, F.R.S.	The Atlantic Telegraph.
	Rev. Dr. Livingstone, D.C.L. ...	Recent discoveries in Africa.
1858. Leeds.........	Prof. J. Phillips, LL.D., F.R.S.	The Ironstones of Yorkshire.
	Prof. R. Owen, M.D., F.R.S. ...	The Fossil Mammalia of Australia.
1859. Aberdeen ...	Sir R. I. Murchison, D.C.L.	Geology of the Northern Highlands.
	Rev. Dr. Robinson, F.R.S.	Electrical Discharges in highly rarefied Media.
1860. Oxford	Rev. Prof. Walker, F.R.S.	Physical Constitution of the Sun.
	Captain Sherard Osborn, R.N. .	Arctic Discovery.
1861. Manchester .	Prof. W. A. Miller, M.A., F.R.S.	Spectrum Analysis.
	G. B. Airy, F.R.S., Astron. Roy. .	The late Eclipse of the Sun.
1862, Cambridge .	Prof. Tyndall, LL.D., F.R.S. ...	The Forms and Action of Water.
	Prof. Odling, F.R.S.	Organic Chemistry.
1863. Newcastle-on-Tyne.	Prof. Williamson, F.R.S.	The Chemistry of the Galvanic Battery considered in relation to Dynamics.

Date and Place.	Lecturer.	Subject of Discourse.
1863. Newcastle-on-Tyne.	James Glaisher, F.R.S.	The Balloon Ascents made for the British Association.
1864. Bath	Prof. Roscoe, F.R.S.	The Chemical Action of Light.
	Dr. Livingstone, F.R.S.	Recent Travels in Africa.
1865. Birmingham	J. Beete Jukes, F.R.S.	Probabilities as to the position and extent of the Coal-measures beneath the red rocks of the Midland Counties.
1866. Nottingham.	William Huggins, F.R.S.	The results of Spectrum Analysis applied to Heavenly Bodies.
	Dr. J. D. Hooker, F.R.S.	Insular Floras.
1867. Dundee	Archibald Geikie, F.R.S.	The Geological origin of the present Scenery of Scotland.
	Alexander Herschel, F.R.A.S.	The present state of knowledge regarding Meteors and Meteorites.
1868. Norwich	J. Fergusson, F.R.S.	Archæology of the early Buddhist Monuments.
	Dr. W. Odling, F.R.S.	Reverse Chemical Actions.
1869. Exeter	Prof. J. Phillips, LL.D., F.R.S.	Vesuvius.
	J. Norman Lockyer, F.R.S.	The Physical Constitution of the Stars and Nebulæ.
1870. Liverpool	Prof. J. Tyndall, LL.D., F.R.S.	The Scientific Use of the Imagination.
	Prof. W. J. Macquorn Rankine, LL.D., F.R.S.	Stream-lines and Waves, in connexion with Naval Architecture.
1871. Edinburgh	F. A. Abel, F.R.S.	Some recent investigations and applications of Explosive Agents.
	E. B. Tylor, F.R.S.	The Relation of Primitive to Modern Civilization.
1872. Brighton	Prof. P. Martin Duncan, M.D., F.R.S.	Insect Metamorphosis.
	Prof. W. K. Clifford	The Aims and Instruments of Scientific Thought.
1873. Bradford	Prof. W. C. Williamson, F.R.S.	Coal and Coal Plants.
	Prof. Clerk Maxwell, F.R.S.	Molecules.
1874. Belfast	Sir John Lubbock, Bart., M.P., F.R.S.	Common Wild Flowers considered in relation to Insects.
	Prof. Huxley, F.R.S.	The Hypothesis that Animals are Automata, and its History.
1875. Bristol	William Spottiswoode, LL.D., F.R.S.	The Colours of Polarized Light.
	F. J. Bramwell, F.R.S.	Railway Safety Appliances.

Lectures to the Operative Classes.

1867. Dundee	Prof. J. Tyndall, LL.D., F.R.S.	Matter and Force.
1868. Norwich	Prof. Huxley, LL.D., F.R.S.	A piece of Chalk.
1869. Exeter	Prof. Miller, M.D., F.R.S.	Experimental illustrations of the modes of detecting the Composition of the Sun and other Heavenly Bodies by the Spectrum.
1870. Liverpool	Sir John Lubbock, Bart., M.P., F.R.S.	Savages.
1872. Brighton	William Spottiswoode, LL.D., F.R.S.	Sunshine, Sea, and Sky.
1873. Bradford	C. W. Siemens, D.C.L., F.R.S.	Fuel.
1874. Belfast	Professor Odling, F.R.S.	The Discovery of Oxygen.
1875. Bristol	Dr. W. B. Carpenter, F.R.S.	A piece of Limestone.

THE BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

THE GENERAL TREASURER'S ACCOUNT from August 19, 1874 (commencement of BELFAST Meeting) to August 25, 1875 (BRISTOL). Not including Receipts on account of Bristol Meeting.

RECEIPTS.

	£	s.	d.
alance brought from last Account	714	9	11
eceived for Life Compositions at Bradford Meeting and since	220	0	0
" Annual Subscriptions, ditto ditto	657	0	0
" Associates' Tickets, ditto ditto	817	0	0
" Ladies' Tickets, ditto ditto	630	0	0
" Dividends on Stock	238	0	0
" for Sale of Publications	35	11	4
" Balance of Grant made at Bradford to the Trades Unions Committee	2	19	6
" Balance of Grant made at Bradford to Intestinal Secretions Committee	3	3	10
	3318	4	7
	£3318	4	7

Examined with the vouchers and found correct.

J. H. GLADSTONE,
W. SPOTTISWOODE,
R. STRACHEY, } *Auditors.*

PAYMENTS.

	£	s.	d.	£	s.	d.
Paid Expenses of Belfast Meeting, also Sundry Printing, Binding, Advertising, and Incidental Petty Expenses				405	0	2
" Printing, Engraving, &c. Report of 43rd Meeting, Vol. XLII. (Bradford)				689	6	8
" Printing on account of Report of 44th Meeting, Vol. XLIII. (Belfast)				65	10	1
" Binding Report 1838, Vol. VII.				1	0	0
" Salaries, &c. (1 year)				470	0	0
" Rent and Office Expenses (Albemarle Street)				104	5	0
" Grants made at the Belfast Meeting, viz.—						
Zoological Record	100	0	0			
Chemistry Record	100	0	0			
Committee on Elliptic Functions	100	0	0			
" Anthropological Instructions, &c.	20	0	0			
" Kent's Cavern Exploration	100	0	0			
" Luminous Meteors	30	0	0			
" Intestinal Secretions	20	0	0			
" Palestine Exploration	100	0	0			
" British Rainfall	120	0	0			
" Isomeric Cresols	20	0	0			
" Earthquakes in Scotland	15	0	0			
" Sub-Wealden Explorations	100	0	0			
" Settle Cave Exploration	50	0	0			
" Myxinoid Fishes	20	0	0			
" Underground Waters in New Red Sandstone	10	0	0			
" Magnetization of Iron, &c.	20	0	0			
" Specific Volumes of Liquids	25	0	0			
" Estimation of Potash and Phosphoric Acid	10	0	0			
				960	0	0
1875. Aug. 25. Balance at London and Westminster Bank	£613	1	8			
" in hands of General Treasurer	11	0	0			
				624	1	8
				£3318	4	7

A. W. WILLIAMSON,
August 25, 1875.

Table showing the Attendance and Receipts

Date of Meeting.	Where held.	Presidents.	Old Life Members.	New Life Members.
1831, Sept. 27	York	The Earl Fitzwilliam, D.C.L.	...	...
1832, June 19	Oxford	The Rev. W. Buckland, F.R.S.	...	...
1833, June 25	Cambridge	The Rev. A. Sedgwick, F.R.S.	...	...
1834, Sept. 8	Edinburgh	Sir T. M. Brisbane, D.C.L.	...	...
1835, Aug. 10	Dublin	The Rev. Provost Lloyd, LL.D.	...	...
1836, Aug. 22	Bristol	The Marquis of Lansdowne	...	...
1837, Sept. 11	Liverpool	The Earl of Burlington, F.R.S.	...	...
1838, Aug. 10	Newcastle-on-Tyne	The Duke of Northumberland	...	...
1839, Aug. 26	Birmingham	The Rev. W. Vernon Harcourt	...	...
1840, Sept. 17	Glasgow	The Marquis of Breadalbane	...	...
1841, July 20	Plymouth	The Rev. W. Whewell, F.R.S.	169	65
1842, June 23	Manchester	The Lord Francis Egerton	303	169
1843, Aug. 17	Cork	The Earl of Rosse, F.R.S.	109	28
1844, Sept. 26	York	The Rev. G. Peacock, D.D.	226	150
1845, June 19	Cambridge	Sir John F. W. Herschel, Bart.	313	36
1846, Sept. 10	Southampton	Sir Roderick I. Murchison, Bart.	241	10
1847, June 23	Oxford	Sir Robert H. Inglis, Bart.	314	18
1848, Aug. 9	Swansea	The Marquis of Northampton	149	3
1849, Sept. 12	Birmingham	The Rev. T. R. Robinson, D.D.	227	12
1850, July 21	Edinburgh	Sir David Brewster, K.H.	235	9
1851, July 2	Ipswich	G. B. Airy, Esq., Astron. Royal.	172	8
1852, Sept. 1	Belfast	Lieut.-General Sabine, F.R.S.	164	10
1853, Sept. 3	Hull	William Hopkins, Esq., F.R.S.	141	13
1854, Sept. 20	Liverpool	The Earl of Harrowby, F.R.S.	238	23
1855, Sept. 12	Glasgow	The Duke of Argyll, F.R.S.	194	33
1856, Aug. 6	Cheltenham	Prof. C. G. B. Daubeny, M.D.	182	14
1857, Aug. 26	Dublin	The Rev. Humphrey Lloyd, D.D.	236	15
1858, Sept. 22	Leeds	Richard Owen, M.D., D.C.L.	222	42
1859, Sept. 14	Aberdeen	H.R.H. The Prince Consort	184	27
1860, June 27	Oxford	The Lord Wrottesley, M.A.	286	21
1861, Sept. 4	Manchester	William Fairbairn, LL.D., F.R.S.	321	113
1862, Oct. 1	Cambridge	The Rev. Prof. Willis, M.A.	239	15
1863, Aug. 26	Newcastle-on-Tyne	Sir William G. Armstrong, C.B.	203	36
1864, Sept. 13	Bath	Sir Charles Lyell, Bart., M.A.	287	40
1865, Sept. 6	Birmingham	Prof. J. Phillips, M.A., LL.D.	292	44
1866, Aug. 22	Nottingham	William R. Grove, Q.C., F.R.S.	207	31
1867, Sept. 4	Dundee	The Duke of Buccleuch, K.C.B.	167	25
1868, Aug. 19	Norwich	Dr. Joseph D. Hooker, F.R.S.	196	18
1869, Aug. 18	Exeter	Prof. G. G. Stokes, D.C.L.	204	21
1870, Sept. 14	Liverpool	Prof. T. H. Huxley, LL.D.	314	39
1871, Aug. 2	Edinburgh	Prof. Sir W. Thomson, LL.D.	246	28
1872, Aug. 14	Brighton	Dr. W. B. Carpenter, F.R.S.	245	36
1873, Sept. 17	Bradford	Prof. A. W. Williamson, F.R.S.	212	27
1874, Aug. 19	Belfast	Prof. J. Tyndall, LL.D., F.R.S.	162	13
1875, Aug. 25	Bristol	Sir John Hawkshaw, C.E., F.R.S.	239	36
1876, Sept. 6	Glasgow	Prof. T. Andrews, M.D., F.R.S.		

at Annual Meetings of the Association.

Attended by						Amount received during the Meeting.	Sums paid on Account of Grants for Scientific Purposes.
Old Annual Members.	New Annual Members.	Associates.	Ladies.	Foreigners.	Total.		
						£ s. d.	£ s. d.
...	...	...	...	...	353	....	....
...	...	...	...	...	...	....	....
...	...	...	...	...	900	....	....
...	...	...	...	...	1298	....	20 0 0
...	...	...	...	...	...	....	167 0 0
...	...	...	...	...	1350	....	434 14 0
...	...	...	...	...	1840	. ...	918 14 6
...	...	...	1100*	...	2400	....	956 12 2
...	...	...	...	34	1438	....	1595 11 0
...	...	...	...	40	1353	....	1546 16 4
46	317	...	60*	...	891	....	1235 10 11
75	376	33†	331*	28	1315	....	1449 17 8
71	185	...	160	...	...	....	1565 10 2
45	190	9†	260	...	...	....	981 12 8
94	22	407	172	35	1079	....	830 9 9
65	39	270	196	36	857	....	685 16 0
197	40	495	203	53	1260	....	208 5 4
54	25	376	197	15	929	707 0 0	275 1 8
93	33	447	237	22	1071	963 0 0	159 19 6
128	42	510	273	44	1241	1085 0 0	345 18 0
61	47	244	141	37	710	620 0 0	391 9 7
63	60	510	292	9	1108	1085 0 0	304 6 7
56	57	367	236	6	876	903 0 0	205 0 0
121	121	765	524	10	1802	1882 0 0	330 19 7
142	101	1094	543	26	2133	2311 0 0	480 16 4
104	48	412	346	9	1115	1098 0 0	734 13 9
156	120	900	569	26	2022	2015 0 0	507 15 3
111	91	710	509	13	1698	1931 0 0	618 18 2
125	179	1206	821	22	2564	2782 0 0	684 11 1
177	59	636	463	47	1689	1604 0 0	1241 7 0
184	125	1589	791	15	3139	3944 0 0	1111 5 10
150	57	433	242	25	1161	1089 0 0	1293 16 6
154	209	1704	1004	25	3335	3640 0 0	1608 3 10
182	103	1119	1058	13	2802	2965 0 0	1289 15 8
215	149	766	508	23	1997	2227 0 0	1591 7 10
218	105	960	771	11	2303	2469 0 0	1750 13 4
193	118	1163	771	7	2444	2613 0 0	1739 4 0
226	117	720	682	45‡	2004	2042 0 0	1940 0 0
229	107	678	600	17	1856	1931 0 0	1572 0 0
303	195	1103	910	14	2878	3096 0 0	1472 2 6
311	127	976	754	21	2463	2575 0 0	1285 0 0
280	80	937	912	43	2533	2649 0 0	1685 0 0
237	99	796	601	11	1983	2102 0 0	1151 16 0
232	85	817	630	12	1951	1979 0 0	960 0 0
307	93	884	672	17	2248	2397 0 0	

* Ladies were not admitted by purchased Tickets until 1843.

† Tickets for admission to Sections only. ‡ Including Ladies.

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W. Spottiswoode, Esq., F.R.S.
Major-General Strachey, F.R.S.

Report of the Council for the Year 1874-75, *presented to the General Committee at Bristol on Wednesday, August* 25*th*, 1875.

The Council have received Reports during the past year from the General Treasurer; and his Account for the year will be laid before the General Committee this day.

The General Committee at Belfast referred the following four Resolutions to the Council for their consideration, and they beg to report their proceedings in each case:—

> *First Resolution.*—"That the Council be requested to take such steps as they may deem expedient to urge upon the Government of India the desirableness of continuing Solar Observations in India."

The Council, having considered this Resolution, requested the President to embody their views in a Letter to the Government of India. The following is a copy of the letter to the Marquis of Salisbury:—

"British Association for the Advancement of Science,
22 Albemarle Street, London, March 5, 1875.

"MY LORD,—By the desire of the General Committee and of the Council of the British Association, I beg to lay before your Lordship the accompanying resolutions regarding the continuance of Solar Observations in India.

"Researches of the character here contemplated are of comparatively recent date, and have been hitherto pursued with conspicuous ability by independent observers. They may be divided into three distinct groups:—namely, Sun-spot Periodicity; the relation of that Periodicity to Terrestrial and Planetary phenomena; and the Physical and Chemical changes of the sun's visible surface. It is the opinion of the Council of the British Association that observations of the sun conducted under these three heads would furnish results of the highest scientific importance, and that India, presenting as it does every diversity of climate and of atmospheric condition, and every degree of elevation from the sea-level to the greatest mountain heights, is a field eminently suited to the successful prosecution of such observations.

"The specific proposal which, on behalf of the British Association, I have the honour to submit for your Lordship's consideration is, that the instruments recently supplied for the Observation of the Transit of Venus should, now that they have served that purpose, be made to contribute to the equipment of a Physical Observatory to be established in the Himalayas, the Nielgherries, or some other fit locality. These instruments are suitable for solar observations, and with the addition of a spectroscope and a few other minor adjuncts would suffice for the present. They would be ready to be brought into practical action the moment the necessary buildings, which might be of the simplest and most inexpensive character, are erected.

"But to extract from solar observations their full value it is necessary that they should be continuous. No day ought to pass without observations of the solar surface. This can only be accomplished by establishing, in connexion with the principal observatory, stations in positions selected with the view of rendering it in the highest degree probable that at one or other of them favourable weather would always be found. When, therefore, the results obtained in the proposed observatory shall have justified the extension (and of such justification the Council entertain a confident hope), outlying stations may be added, provided with the moderate equipment needed to multiply the chances of that continuity of observation which it is so desirable to secure.

"It is specially agreeable to me, personally, to have the privilege of bringing this important question under the notice of a nobleman whose scientific acquirements render unnecessary any lengthened argument to prove that the proposed observatory is likely to redound to the honour of England, and to materially assist in the advancement of Natural Knowledge.

"I have the honour to be,
"My Lord,
"Your most obedient Servant,
"JOHN TYNDALL,
President."

"*The Most Honourable*
The Marquis of Salisbury,
Secretary of State for India."

A copy of this Letter was forwarded to the Governor-General of India.

The following reply has been received from the Secretary of State for India:—

"India Office, Westminster, S.W.,
April 2, 1875.

"SIR,—I am directed by the Secretary of State for India in Council to acknowledge the receipt of your letter of the 5th March, setting forth the desirability of instituting continuous Solar Observations in India, and, in reply, to transmit to you a copy of a Despatch which his Lordship has addressed to the Government of India on the subject.

"I am, Sir,
"Your obedient Servant,
"LOUIS MALLET."

"*Professor Tyndall, F.R.S.*"

"'Geographical (Observatories),
No. 16.

"'*To His Excellency The Right Honourable the Governor-General of India in Council.*

"'India Office, London,
March 24, 1875.

"'MY LORD,—Para. 1. I have received and considered in Council your Excellency's Despatch, dated 12th February (No. 2, Industry, Science, and Art), 1875, reporting your sanction of an arrangement by which Lieutenant-Colonel Tennant, with a small establishment, will be employed, during the year 1875–76, to make observations, at Roorkee, of the sun and of Jupiter's satellites, and to reduce the transit-observations. The instruments* for use at Roorkee will be ordered in this country, and sent out with as little delay as possible.

"'2. I observe that your Government, in sanctioning these arrangements, have declined to engage themselves to any thing further at present; and that the suggested establishment of a solar observatory at Simla remains an open question for future consideration.

"'3. I herewith transmit a copy of a letter, which I have received from the President of the British Association, on the importance of continuous Solar Observations in India; and I would suggest for your consideration whether an observatory on an inexpensive scale might not usefully be established at Simla after the ensuing year, with this object, for which spectroscopes only would be necessary, in addition to the instruments already at Roorkee.

"'I have the honour to be,
"'My Lord,
"'Your Lordship's most obedient humble Servant,
(Signed) "'SALISBURY.'"

Second Resolution.—"That the Council of the Association be requested to take such steps as they may think desirable with a view to promote the appointment of Naturalists to vessels engaged on the coasts of little-known parts of the world."

The Council drew up the following Letter, which was signed by the President, and forwarded to the Admiralty:—

"British Association for the Advancement of Science,
22 Albemarle Street, London, March 9, 1875.

"SIR,—The Council of the British Association have had recently referred to them by the General Committee of the Association a question which in various forms has been already under their consideration—the importance, namely, of attaching Naturalists (that is to say, persons specially trained in Natural-history observation) to Surveying-ships generally, and more especially to those engaged in the survey of unfrequented or little-known regions.

"The Council have requested me to communicate to Her Majesty's Government their conviction of the importance of making, wherever practicable, this addition to Surveying Expeditions. They believe that such action on the part of the Government would not only be of advantage to Science, but that it would be conducive to the commercial interests of the country to an extent far outbalancing the trifling outlay which such appointments would render necessary.

"We are here in reality only asking for a further application of the enlightened policy which enabled the Government to utilize the talents of such men as Banks and Solander in the last century, and which has more recently given scope to the abilities of such men as Darwin, Hooker, and Huxley. Even in a commercial point of view the advantages which have flowed from this policy have been quite out of proportion to its cost to the country.

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* "'A parallel wire micrometer	£ 20
Solar and stellar spectroscopes	130
Micrometer for measuring solar photographs	50
	£200

"The obvious desirability of associating trained observers with the Surveys of the future is thus strengthened by the experience of the past. The Council of the British Association beg therefore to urge upon the favourable consideration of Her Majesty's Government the question submitted to them by the General Committee.

"I have the honour &c."

"*Vernon Lushington, Esq., Q.C.*"

The following reply has been received from the Admiralty:—

"Admiralty,
March 29, 1875.

"SIR,—I am commanded by My Lords Commissioners of the Admiralty to thank you for your letter of the 9th instant, conveying the opinion expressed by the Committee of the British Association for the Advancement of Science as to the desirability of trained Naturalists being attached to all Surveying-vessels, more especially to those engaged in the survey of unfrequented regions.

"I am, Sir,
"Your obedient Servant,
"ROBERT HALL."

"*The President of the British Association
for the Advancement of Science,
22 Albemarle Street, S.W.*"

Third Resolution.—"That the Council be requested to take such steps as they may think desirable with the view of promoting any application that may be made to Her Majesty's Government by the Royal Society for a systematic Physical and Biological exploration of the seas around the British Isles."

The Council deferred the consideration of this Resolution until action be taken by the Royal Society.

Fourth Resolution.—"That the Council should take such steps as they may think desirable for supporting the request to Her Majesty's Government to undertake an Arctic Expedition on the basis proposed by the Council of the Royal Geographical Society at the beginning of the present year, which it is understood will be again made by that body."

The Council are glad to report that the efforts of the Learned Societies to obtain a renewal of the Exploration of the Polar Seas have been crowned with success; the Expedition which has been despatched on this service has been furnished with the best-known appliances for the furtherance of the objects in view.

The Council have added the following list of names of gentlemen present at the last Meeting of the Association to the list of Corresponding Members:—

M. A. Niaudet Breguet.
M. Ch. d'Almeida.
Dr. W. Feddersen.
Dr. Knoblauch.
Dr. G. Schweinfurth.
Professor Wiedemann.

The Council have been informed that the invitation to hold the Annual Meeting of the Association in 1877 at Plymouth will be renewed, and that an invitation for a future Meeting will be presented from Leeds.

In accordance with the regulations adopted at the Belfast Meeting for the selection of Ordinary Members of Council, the Council append a list of the Members of the present Council who are not proposed for re-election for the ensuing year:—

Dr. Beddoe.
Dr. Debus.
Mr. Fitch.
Mr. Sclater.
General Strachey.

The Council recommend the re-election of the other Members of the Council, with the addition of the following gentlemen:—

Mr. F. A. Abel.
Mr. John Evans.
Mr. J. Heywood.
Professor A. Newton.
Professor Rolleston.

RECOMMENDATIONS ADOPTED BY THE GENERAL COMMITTEE AT THE BRISTOL MEETING IN AUGUST 1875.

[When Committees are appointed, the Member first named is regarded as the Secretary, except there is a specific nomination.]

Involving Grants of Money.

That the Committee, consisting of Professor Cayley, Professor G. G. Stokes, Professor H. J. S. Smith, Professor Sir W. Thomson, and Mr. J. W. L. Glaisher (Secretary), be reappointed; that the sum of £59 4*s.* 2*d.* be placed at their disposal as a final payment on account of expenses incurred in the calculation of the Elliptic Functions, and that a further sum of £100 be placed at the disposal of the Committee for the purpose of continuing the printing of the tables of Elliptic Functions.

That the Committee on the Rainfall of the British Isles, consisting of Mr. C. Brooke, Mr. J. Glaisher, Mr. J. F. Bateman, Mr. T. Hawksley, Mr. G. J. Symons, Mr. C. Tomlinson, Mr. Rogers Field, the Earl of Rosse, and Mr. J. Smyth, Jun., be reappointed; that Mr. G. J. Symons be the Secretary, and that the sum of £100 be placed at their disposal for the purpose, with the understanding that £60 is for completing the observations in Great Britain, and that £40 be devoted to observations in Ireland.

That the Committee, consisting of Mr. James Glaisher, Mr. R. P. Greg, Mr. Charles Brooke, Dr. Flight, Professor G. Forbes, and Professor A. S. Herschel, on Luminous Meteors, be reappointed, and that a grant of £30 be placed at their disposal.

That the Committee, consisting of Professor Clerk Maxwell, Professor J. D. Everett, and Mr. A. Schuster, for testing experimentally the exactness of Ohm's law, be reappointed, and that the grant of £50 which has lapsed be renewed.

That the Committee, consisting of Professor Stokes, Dr. De La Rue, Professor Clerk Maxwell, Mr. W. F. Barrett, Mr. Howard Grubb, Mr. G. Johnstone Stoney, and Professor R. S. Ball, for examining and reporting upon the reflective powers of silver, gold, and platinum, whether in mass or chemically deposited on glass, and of speculum metal, be reappointed, and that the grant of £20 which has lapsed be renewed.

That the Committee on Thermo-Electricity, consisting of Professor Tait, Professor Tyndall, and Professor Balfour Stewart, be reappointed, and that the grant of £50 which has lapsed be renewed.

That Sir W. Thomson, Professor J. C. Adams, Rear-Admiral Richards, General Strachey, Mr. W. Parkes, Colonel Walker, Professor Guthrie, Mr. J. W. L. Glaisher, Mr. John Exley, Mr. J. N. Schoolbred, and Mr. J. R. Napier, be appointed a Committee on Tides, and that the sum of £200 be placed at their disposal for completing and setting up in a locality in London, where it may be available for use, Sir William Thomson's Tide Calculating Machine.

That Professors Roscoe, Balfour Stewart, and Thorpe be reappointed as a Committee for the purpose of determining the Specific Volumes of Liquids; that Dr. Thorpe be the Secretary, and that the sum of £25 be placed at their disposal for the purpose.

That Dr. Armstrong, Professor Thorpe, and Mr. W. W. Fisher, be a Committee for the purpose of investigating Isomeric Cresols, and the Law which governs Substitution in the Phenol Series; that Dr. Armstrong be the Secretary, and that the sum of £10 be placed at their disposal for the purpose.

That Mr. Frank Clowes, B.Sc. and Dr. W. A. Tilden be a Committee for the purpose of examining the Action of Ethylbromo-butyrate on Ethyl Sodaceto-acetate; that Mr. Clowes be the Secretary, and that the sum of £10 be placed at their disposal for the purpose.

That Messrs. Allen, Dewar, Stanford, and Fletcher be a Committee for the purpose of examining and reporting upon the methods employed in the estimation of Potash and Phosphoric Acid in commercial products, and on the mode of stating the results; that Mr. Allen be the Secretary, and that the sum of £20 be placed at their disposal for the purpose.

That Sir John Lubbock, Bart., Professor Prestwich, Professor Busk, Professor Hughes, Professor W. Boyd Dawkins, Rev. H. W. Crosskey, Messrs. L. C. Miall and R. H. Tiddeman be a Committee for the purpose of assisting in the exploration of the Victoria Cave; that Mr. Tiddeman be the Secretary, and that the sum of £100 be placed at their disposal for the purpose.

That Messrs. J. Evans, W. Carruthers, F. Drew, R. Etheridge, Jun., A. H. Green, G. A. Lebour, L. C. Miall, H. A. Nicholson, W. Topley, and W. Whitaker be a Committee for the purpose of carrying on the Geological Record; that Mr. Whitaker be the Secretary, and that the sum of £100 be placed at their disposal for the purpose.

That Mr. J. Evans, Sir J. Lubbock, Bart., Mr. E. Vivian, Mr. W. Pengelly, Mr. G. Busk, Professor W. Boyd Dawkins, Mr. W. Ashford Sanford, and Mr. J. E. Lee be a Committee for the purpose of continuing the exploration of Kent's Cavern, Torquay; that Mr. Pengelly be the Secretary, and that the sum of £100 be placed at their disposal for the purpose.

That Professor A. S. Herschel and Mr. G. A. Lebour be reappointed a Committee for the purpose of making experiments on the Thermal Conductivities of certain rocks; that Professor Herschel be the Secretary, and that the sum of £10 be placed at their disposal for the purpose.

That Professor Hull, Mr. E. W. Binney, Mr. H. Howell, Mr. M. Reade, Rev. H. W. Crosskey, Professor A. H. Green, Professor Harkness, Mr. W. Molyneux, Mr. G. H. Morton, Mr. Pengelly, Professor Prestwich, Mr. J. Plant, Mr. W. Whitaker, Captain D. Galton, and Mr. De Rance be reappointed a Committee for the purpose of investigating the circulation of the underground waters in the New Red Sandstone and Permian formations of England, and the quantity and character of the water supplied to various towns and districts from those formations; that Mr. C. E. De Rance be the Secretary, and that the sum of £10 be placed at their disposal for the purpose.

That Dr. Bryce, Mr. J. Brough, Mr. G. Forbes, Mr. D. Milne-Home, Mr. J. Thomson, Professor Sir W. Thomson, and Mr. Peter Drummond be a Committee for the purpose of continuing the Observations and Records of Earthquakes in Scotland; that Dr. Bryce be the Secretary, and that the sum of £20 be placed at their disposal for the purpose.

That Mr. Sclater, Mr. Rye, and Mr. McLachlan be a Committee for the purpose of continuing the Zoological Record; that Mr. Rye be the Secretary, and that the sum of £100 be placed at their disposal for the purpose.

That Mr. Dresser, Mr. Barnes, Mr. Harland, Mr. Harting, Professor Newton, and Canon Tristram be reappointed a Committee for the purpose of considering the desirability of establishing "a close time" for the protection of indigenous animals; that Mr. Dresser be the Secretary, and that the sum of £5 be placed at their disposal for the purpose.

That Professor Balfour, Professor Dewar, and Dr. McKendrick be a Committee for the purpose of investigating the Physiological Action of Sound; that Dr. McKendrick be the Secretary, and that the sum of £25 be placed at their disposal for the purpose.

That Professor Huxley, Mr. Sclater, Mr. F. M. Balfour, Dr. M. Foster, Mr. Ray Lankester, and Mr. Dew-Smith (Secretary) be a Committee for the purpose of arranging with Dr. Dohrn for the occupation of a Table at the Zoological Station at Naples during the ensuing year, in accordance with their Report; that Mr. Dew-Smith be the Secretary, and that the sum of £75 be placed at their disposal for the purpose.

That Dr. Lauder Brunton and Dr. Pye-Smith be reappointed a Committee for the purpose of making physiological researches on the nature of Intestinal Secretions; that Dr. Brunton be the Secretary, and that the sum of £20 be placed at their disposal for the purpose.

That Colonel Lane Fox, Mr. John Evans, and Professor Rolleston be a Committee for the purpose of Prehistoric Explorations; that Colonel Lane Fox be the Secretary, and that the sum of £25 be placed at their disposal for the purpose.

That the Committee, consisting of Colonel Lane Fox, Dr. Beddoe, Mr. Franks, Mr. F. Galton, Mr. E. W. Brabrook, Sir J. Lubbock, Sir W. Elliot, Mr. C. R. Markham, Mr. E. B. Tylor, Mr. J. Evans, and Mr. F. W. Rudler, be reappointed for the purpose of preparing and publishing brief forms of instruction for travellers, ethnologists, and other anthropological observers; that Colonel Lane Fox be the Secretary, and that the sum of £25 be placed at their disposal for the purpose.

That Dr. Beddoe, Lord Aberdare, Dr. Farr, Mr. Francis Galton, Sir Henry Rawlinson, Colonel Lane Fox, Mr. Rawson Rawson, Mr. James Heywood, Dr. Mouat, Professor Rolleston, Mr. Hallett, Mr. Fellows, and Professor Leone Levi (with power to add to their number), be an Anthropometric Committee for the purpose of collecting observations on the Systematic Examination of the Heights, Weights, and other physical characters of the inhabitants of the British Isles; that Mr. Francis Galton be the Secretary, and that the sum of £100 be placed at their disposal for the purpose.

That the Committee on instruments for measuring the speed of ships be reappointed; that it consist of the following Members:—Mr. W. Froude, Mr. F. J. Bramwell, Mr. A. E. Fletcher, Rev. E. L. Berthon, Mr. James R. Napier, Mr. C. W. Merrifield, Dr. C. W. Siemens, Mr. H. M. Brunel, Mr. W. Smith, Sir William Thomson, Mr. J. N. Shoolbred, and Professor James Thomson; that Mr. J. N. Shoolbred be the Secretary, and that the sum of £50 be placed at their disposal for the purpose.

That Mr. James R. Napier, Sir William Thomson, Mr. William Froude, and Professor Osborne Reynolds be a Committee for the purpose of making experiments and of reporting on the effect of the propeller on the turning of Steam-vessels; that Professor Osborne Reynolds be the Secretary, and that the sum of £50 be placed at their disposal for the purpose.

Applications for Reports and Researches not involving Grants of Money.

That the Committee on Underground Temperature, consisting of Professor Everett (Secretary), Professor Sir W. Thomson, Professor J. Clerk Maxwell, Mr. G. J. Symons, Professor Ramsay, Professor Geikie, Mr. J. Glaisher, Mr. George Maw, Mr. Pengelly, Professor Edward Hull, Professor Ansted, Dr. Clement Le Neve Foster, Professor A. S. Herschel, Mr. G. A. Lebour, Colonel Strange, and Mr. A. B. Wynne, be reappointed.

That the Committee on the Magnetization of Iron, Nickel, and Cobalt, consisting of Professor Balfour Stewart, Professor Clerk Maxwell, Mr. H. A. Rowland, and Professor W. F. Barrett, be reappointed.

That the Committee, consisting of Professor Sylvester, Professor Cayley, Professor Hirst, Rev. Professor Bartholomew Price, Professor H. J. S. Smith, Dr. Spottiswoode, Mr. R. B. Hayward, Dr. Salmon, Rev. Professor R. Townsend, Professor Fuller, Professor Kelland, Mr. J. M. Wilson, Professor Henrici, Mr. J. W. L. Glaisher, and Professor Clifford, for considering the possibility of improving the methods of instruction in elementary geometry, be reappointed, and that they be requested to consider the Syllabus drawn up by the Association for the Improvement of Geometrical Teaching, and report thereon.

That the Committee, consisting of Dr. Joule, Professor Sir W. Thomson, Professor Tait, Professor Balfour Stewart, and Professor J. Clerk Maxwell, for effecting the determination of the Mechanical Equivalent of Heat, be reappointed.

That the Committee, consisting of Professor H. J. S. Smith, Professor Clifford, Professor W. G. Adams, Professor Balfour Stewart, Mr. J. G. Fitch, Mr. George Griffith, Mr. Marshall Watts, Professor G. Carey Foster, Mr. W. F. Barrett, Professor Clerk Maxwell, and Mr. G. F. Rodwell, for considering and reporting on the extent and method of Teaching Physics in Schools, be reappointed, and that Professor G. C. Foster be the Secretary.

That Mr. Spottiswoode, Professor Stokes, Professor Cayley, Professor H. J. S. Smith, Sir W. Thomson, Professor Henrici, Lord Rayleigh, and Mr. J. W. L. Glaisher be appointed a Committee to report on Mathematical Notation.

That Mr. W. H. L. Russell be requested to continue his Report on Hyperelliptic Functions.

That Dr. Atkinson, Professor Gladstone, and Mr. A. Vernon Harcourt, be a Committee for the purpose of collecting and suggesting subjects for Chemical Researches; that Dr. Atkinson be the Secretary.

That R. B. Grantham, C.E., F.G.S., Professor A. W. Williamson, F.R.S., Dr. Gilbert, F.R.S., Professor Corfield, M.D., F. J. Bramwell, C.E., F.R.S., W. Hope, V.C., and J. W. Barry, C.E., be a Committee for the purpose of continuing the investigations on the Treatment and Utilization of Sewage; that Dr. Corfield be the Secretary.

That Professor Prestwich, Professor Harkness, Professor Hughes, Professor W. Boyd Dawkins, Rev. H. W. Crosskey, Messrs. L. C. Miall, G. H. Morton, D. Mackintosh, R. H. Tiddeman, J. E. Lee, T. Plant, W. Pengelly, and Dr. Deane be a Committee for the purpose of recording the position, height above the sea, lithological characters, size, and origin of the Erratic Blocks of England, Wales, and Ireland, reporting other matters of interest connected with the same, and taking measures for their preservation; that the Rev. H. W. Crosskey be the Secretary.

That Mr. Spence Bate be requested to continue his Report on our present knowledge of the Crustacea.

That Mr. J. J. Hubbard, M.P., Mr. Chadwick, M.P., Mr. Morley, M.P., Dr. Farr, Mr. Hallett, Professor Jevons, Mr. Newmarch, Professor Leone Levi, Mr. Heywood, Mr. Shaen (with power to add to their number) be a Committee for the purpose of considering and reporting on the practicability of adopting a Common Measure of Value in the Assessment of Direct Taxation, Local and Imperial, and that Mr. Hallett be the Secretary.

That the Committee, consisting of Lord Houghton, Professor Thorold Rogers, W. Newmarch, Professor Fawcett, M.P., Jacob Behrens, F. P. Fellows, R. H. Inglis Palgrave, Archibald Hamilton, Rev. Dr. Percival, Mr. F. Bennoch, Mr. T. Sopwith, F.R.S., Mr. Morley, M.P., and Mr. Chadwick, M.P., on Capital and Labour, be reappointed; that Professor Leone Levi be the Secretary.

That the Metric Committee, consisting of James Heywood, M.A., F.R.S., Lord O'Hagan, Sir W. Armstrong, F.R.S., William Farr, M.D., D.C.L., F.R.S., John Beddoe, M.D., F.R.S., Dr. Mouat, P. Hallett, M.A., Professor Hennessy, F.R.S., W. P. Price, Rev. Dr. Percival, Frank P. Fellows, F.S.S., C. W. Siemens, F.R.S., Professor A. W. Williamson, F.R.S., and Professor Leone Levi, be reappointed for the purpose of reporting upon the best means of providing uniformity of weights and measures with reference to the interests of science; that Professor Leone Levi be the Secretary.

That the Committee, consisting of Professor Cayley, Mr. J. W. L. Glaisher, Dr. W. Pole, Mr. C. W. Merrifield, Professor Fuller, Mr. H. M. Brunel, and Professor W. K. Clifford, be reappointed to estimate the cost of constructing Mr. Babbage's Analytical Engine, and to consider the advisability of printing tables by its means.

That the Committee for the purpose of considering the use of steel for structural purposes be reappointed, consisting of Mr. W. Barlow, Mr. H. Bessemer, Mr. F. J. Bramwell, Captain Douglas Galton, Sir John Hawkshaw, Dr. C. W. Siemens, Professor Abel, and Mr. E. H. Carbutt; that Mr. E. H. Carbutt be the Secretary.

That the Committee for considering and reporting upon British Measures, consisting of Mr. F. J. Bramwell, Mr. J. R. Napier, Mr. C. W. Merrifield, Sir John Hawkshaw, and Professor Osborne Reynolds, be reappointed.

That Sir William Thomson, Major-General Strachey, Captain Douglas Galton, Mr. G. F. Deacon, Mr. Rogers Field, Mr. E. Roberts, and Mr. James N. Shoolbred be a Committee for the purpose of considering the Datum-level of the Ordnance Survey of Great Britain, with a view to its establishment on a surer foundation than hitherto, with power to communicate with the Government if necessary; that Mr. James N. Shoolbred be the Secretary.

Communications ordered to be printed in extenso *in the Annual Report of the Association.*

That Professor Cayley's paper "On the analytical forms called Trees, with application to the Theory of Chemical Combinations," be printed *in extenso* in the Reports of the Association.

That the paper of Professor Osborne Reynolds "On the Steering of Screw-steamers" be printed *in extenso* in the Reports of the Association.

That the paper of Mr. Thomas Howard "On the River Avon" be printed *in extenso* in the Proceedings of the Sections of the Association, together with the necessary Plates.

That Mr. J. N. Shoolbred's paper "On the Half-tide Level at Liverpool" be printed *in extenso* in the Reports of the Association, together with the necessary Plates.

Resolutions referred to the Council for consideration and action if it seem desirable.

That the Council be requested to consider the recommendations of the Reports of the Royal Commission on Scientific Instruction and the Advancement of Science, and to take such action thereupon as may seem to them best calculated to advance the interests of Natural Science.

That the Council be requested to take such steps as they think suitable for renewing their representations to the Secretary of State for India, as to the importance of establishing an Observatory for Solar Physics in India, in conformity with the recommendations of the Royal Commissioners on Scientific Instruction and the Advancement of Science.

That the Council be requested to consider and report upon the manner in which the Members of Committees and other Officers of the Association shall be selected, and whether Ladies shall be admitted to such offices, and if so, to what offices, and under what conditions.

That the Council be requested to take into consideration the expediency of appointing Representatives to attend the International Statistical Congress, to be held at Buda-Pesth, in 1876.

Synopsis of Grants of Money appropriated to Scientific Purposes by the General Committee at the Bristol Meeting in August 1875. *The names of the Members who would be entitled to call on the General Treasurer for the respective Grants are prefixed.*

Mathematics and Physics.

*Cayley, Professor.—Printing Mathematical Tables	£159	4	2
*Brooke, Mr.—British Rainfall	100	0	0
*Glaisher, Mr. J.—Luminous Meteors	30	0	0
*Maxwell, Professor C.—Testing the Exactness of Ohm's Law	50	0	0
*Stokes, Professor.—Reflective Power of Silver and other Substances	20	0	0
*Tait, Professor.—Thermo-Electricity (renewed)	50	0	0
Thomson, Sir William.—Tide Calculating Machine	200	0	0

Chemistry.

*Roscoe, Professor.—Specific Volumes of Liquids	25	0	0
*Armstrong, Dr.—Isomeric Cresols and their Derivatives	10	0	0
Clowes, Mr.—Action of Ethylbromo-butyrate on Ethyl Sod-aceto-acetate	10	0	0
*Allen, Mr.—Estimation of Potash and Phosphoric Acid	20	0	0

Geology.

*Lubbock, Sir J.—Exploration of Victoria Cave, Settle	100	0	0
Evans, Mr. J.—Geological Record	100	0	0
Evans, Mr. J.—Kent's Cavern Exploration	100	0	0
*Herschel, Professor.—Thermal Conducting-power of Rocks	10	0	0
*Hull, Professor.—Underground Waters in New Red Sand-Stone and Permian	10	0	0
*Bryce, Dr.—Earthquakes in Scotland	20	0	0

Biology.

Sclater, Mr.—Zoological Record	100	0	0
Dresser, Mr.—Indigenous Animals "Close Time"	5	0	0
Balfour, Professor.—Physiological Action of Sound	25	0	0
Huxley, Professor.—Table at the Zoological Station at Naples	75	0	0
Carried forward	£1219	4	2

* Reappointed.

Brought forward	£1219	4	2
*Brunton, Dr.—The Nature of Intestinal Secretion	20	0	0
Fox, Col. Lane.—Prehistoric Explorations	25	0	0
*Fox, Col. Lane.—Forms of Instructions for Travellers	25	0	0

Statistics and Economic Science.

Beddoe, Dr.—Systematic Examination of Heights, Weights, of the Inhabitants of the British Isles	100	0	0

Mechanics.

*Froude, Mr. W.—Instruments for Measuring the Speed of Ships and Currents (renewed)	50	0	0
Napier, Mr. J. R.—Effect of the Propeller on the turning of Steam-vessels	50	0	0
Total	£1489	4	2

* Reappointed.

The Annual Meeting in 1876.

The Meeting at Glasgow will commence on Wednesday, September 6, 1876.

Place of Meeting in 1877.

The Annual Meeting of the Association in 1877 will be held at Plymouth.

General Statement of Sums which have been paid on Account of Grants for Scientific Purposes.

	£	s.	d.
1834.			
Tide Discussions	20	0	0
1835.			
Tide Discussions	62	0	0
British Fossil Ichthyology	105	0	0
	£167	0	0
1836.			
Tide Discussions	163	0	0
British Fossil Ichthyology	105	0	0
Thermometric Observations, &c.	50	0	0
Experiments on long-continued Heat	17	1	0
Rain-Gauges	9	13	0
Refraction Experiments	15	0	0
Lunar Nutation	60	0	0
Thermometers	15	6	0
	£434	14	0
1837.			
Tide Discussions	284	1	0
Chemical Constants	24	13	6
Lunar Nutation	70	0	0
Observations on Waves	100	12	0
Tides at Bristol	150	0	0
Meteorology and Subterranean Temperature	89	5	0
Vitrification Experiments	150	0	0
Heart Experiments	8	4	6
Barometric Observations	30	0	0
Barometers	11	18	6
	£918	14	6
1838.			
Tide Discussions	29	0	0
British Fossil Fishes	100	0	0
Meteorological Observations and Anemometer (construction)	100	0	0
Cast Iron (Strength of)	60	0	0
Animal and Vegetable Substances (Preservation of)	19	1	10
Railway Constants	41	12	10
Bristol Tides	50	0	0
Growth of Plants	75	0	0
Mud in Rivers	3	6	6
Education Committee	50	0	0
Heart Experiments	5	3	0
Land and Sea Level	267	8	7
Subterranean Temperature	8	6	0
Steam-vessels	100	0	0
Meteorological Committee	31	9	5
Thermometers	16	4	0
	£956	12	2
1839.			
Fossil Ichthyology	110	0	0
Meteorological Observations at Plymouth	63	10	0
Mechanism of Waves	144	2	0
Bristol Tides	35	18	6
Meteorology and Subterranean Temperature	21	11	0
Vitrification Experiments	9	4	7
Cast-Iron Experiments	100	0	0
Railway Constants	28	7	2
Land and Sea Level	274	1	4
Steam-vessels' Engines	100	0	0
Stars in Histoire Céleste	331	18	6
Stars in Lacaille	11	0	0
Stars in R.A.S. Catalogue	6	16	6
Animal Secretions	10	10	0
Steam-engines in Cornwall	50	0	0
Atmospheric Air	16	1	0
Cast and Wrought Iron	40	0	0
Heat on Organic Bodies	3	0	0
Gases on Solar Spectrum	22	0	0
Hourly Meteorological Observations, Inverness and Kingussie	49	7	8
Fossil Reptiles	118	2	9
Mining Statistics	50	0	0
	£1595	11	0
1840.			
Bristol Tides	100	0	0
Subterranean Temperature	13	13	6
Heart Experiments	18	19	0
Lungs Experiments	8	13	0
Tide Discussions	50	0	0
Land and Sea Level	6	11	1
Stars (Histoire Céleste)	242	10	0
Stars (Lacaille)	4	15	0
Stars (Catalogue)	264	0	0
Atmospheric Air	15	15	0
Water on Iron	10	0	0
Heat on Organic Bodies	7	0	0
Meteorological Observations	52	17	6
Foreign Scientific Memoirs	112	1	6
Working Population	100	0	0
School Statistics	50	0	0
Forms of Vessels	184	7	0
Chemical and Electrical Phenomena	40	0	0
Meteorological Observations at Plymouth	80	0	0
Magnetical Observations	185	13	9
	£1546	16	4
1841.			
Observations on Waves	30	0	0
Meteorology and Subterranean Temperature	8	8	0
Actinometers	10	0	0
Earthquake Shocks	17	7	0
Acrid Poisons	6	0	0
Veins and Absorbents	3	0	0
Mud in Rivers	5	0	0
Marine Zoology	15	12	0
Skeleton Maps	20	0	8
Mountain Barometers	6	18	6
Stars (Histoire Céleste)	185	0	0

	£	s.	d.
Stars (Lacaille)	79	5	0
Stars (Nomenclature of)	17	19	6
Stars (Catalogue of)	40	0	0
Water on Iron	50	0	0
Meteorological Observations at Inverness	20	0	0
Meteorological Observations (reduction of)	25	0	0
Fossil Reptiles	50	0	0
Foreign Memoirs	62	0	0
Railway Sections	38	1	6
Forms of Vessels	193	12	0
Meteorological Observations at Plymouth	55	0	0
Magnetical Observations	61	18	8
Fishes of the Old Red Sandstone	100	0	0
Tides at Leith	50	0	0
Anemometer at Edinburgh	69	1	10
Tabulating Observations	9	6	3
Races of Men	5	0	0
Radiate Animals	2	0	0
	£1235	10	11
1842.			
Dynamometric Instruments	113	11	2
Anoplura Britanniæ	52	12	0
Tides at Bristol	59	8	0
Gases on Light	30	14	7
Chronometers	26	17	6
Marine Zoology	1	5	0
British Fossil Mammalia	100	0	0
Statistics of Education	20	0	0
Marine Steam-vessels' Engines	28	0	0
Stars (Histoire Céleste)	59	0	0
Stars (Brit. Assoc. Cat. of)	110	0	0
Railway Sections	161	10	0
British Belemnites	50	0	0
Fossil Reptiles (publication of Report)	210	0	0
Forms of Vessels	180	0	0
Galvanic Experiments on Rocks	5	8	6
Meteorological Experiments at Plymouth	68	0	0
Constant Indicator and Dynamometric Instruments	90	0	0
Force of Wind	10	0	0
Light on Growth of Seeds	8	0	0
Vital Statistics	50	0	0
Vegetative Power of Seeds	8	1	11
Questions on Human Race	7	9	0
	£1449	17	8
1843.			
Revision of the Nomenclature of Stars	2	0	0
Reduction of Stars, British Association Catalogue	25	0	0
Anomalous Tides, Frith of Forth	120	0	0
Hourly Meteorological Observations at Kingussie and Inverness	77	12	8
Meteorological Observations at Plymouth	55	0	0
Whewell's Meteorological Anemometer at Plymouth	10	0	0
Meteorological Observations, Osler's Anemometer at Plymouth	20	0	0
Reduction of Meteorological Observations	30	0	0
Meteorological Instruments and Gratuities	39	6	0
Construction of Anemometer at Inverness	56	12	2
Magnetic Cooperation	10	8	10
Meteorological Recorder for Kew Observatory	50	0	0
Action of Gases on Light	18	16	1
Establishment at Kew Observatory, Wages, Repairs, Furniture and Sundries	133	4	7
Experiments by Captive Balloons	81	8	0
Oxidation of the Rails of Railways	20	0	0
Publication of Report on Fossil Reptiles	40	0	0
Coloured Drawings of Railway Sections	147	18	3
Registration of Earthquake Shocks	30	0	0
Report on Zoological Nomenclature	10	0	0
Uncovering Lower Red Sandstone near Manchester	4	4	6
Vegetative Power of Seeds	5	3	8
Marine Testacea (Habits of)	10	0	0
Marine Zoology	10	0	0
Marine Zoology	2	14	11
Preparation of Report on British Fossil Mammalia	100	0	0
Physiological Operations of Medicinal Agents	20	0	0
Vital Statistics	36	5	8
Additional Experiments on the Forms of Vessels	70	0	0
Additional Experiments on the Forms of Vessels	100	0	0
Reduction of Experiments on the Forms of Vessels	100	0	0
Morin's Instrument and Constant Indicator	69	14	10
Experiments on the Strength of Materials	60	0	0
	£1565	10	2
1844.			
Meteorological Observations at Kingussie and Inverness	12	0	0
Completing Observations at Plymouth	35	0	0
Magnetic and Meteorological Cooperation	25	8	4
Publication of the British Association Catalogue of Stars	35	0	0
Observations on Tides on the East coast of Scotland	100	0	0
Revision of the Nomenclature of Stars 1842	2	9	6
Maintaining the Establishment in Kew Observatory	117	17	3
Instruments for Kew Observatory	56	7	3

	£	s.	d.
Influence of Light on Plants	10	0	0
Subterraneous Temperature in Ireland	5	0	0
Coloured Drawings of Railway Sections	15	17	6
Investigation of Fossil Fishes of the Lower Tertiary Strata	100	0	0
Registering the Shocks of Earthquakes 1842	23	11	10
Structure of Fossil Shells	20	0	0
Radiata and Mollusca of the Ægean and Red Seas 1842	100	0	0
Geographical Distributions of Marine Zoology 1842	10	0	0
Marine Zoology of Devon and Cornwall	10	0	0
Marine Zoology of Corfu	10	0	0
Experiments on the Vitality of Seeds	9	0	3
Experiments on the Vitality of Seeds 1842	8	7	3
Exotic Anoplura	15	0	0
Strength of Materials	100	0	0
Completing Experiments on the Forms of Ships	100	0	0
Inquiries into Asphyxia	10	0	0
Investigations on the Internal Constitution of Metals	50	0	0
Constant Indicator and Morin's Instrument 1842	10	3	6
	£981	12	8

1845.

	£	s.	d.
Publication of the British Association Catalogue of Stars	351	14	6
Meteorological Observations at Inverness	30	18	11
Magnetic and Meteorological Co-operation	16	16	8
Meteorological Instruments at Edinburgh	18	11	9
Reduction of Anemometrical Observations at Plymouth	25	0	0
Electrical Experiments at Kew Observatory	43	17	8
Maintaining the Establishment in Kew Observatory	149	15	0
For Kreil's Barometrograph	25	0	0
Gases from Iron Furnaces	50	0	0
The Actinograph	15	0	0
Microscopic Structure of Shells	20	0	0
Exotic Anoplura 1843	10	0	0
Vitality of Seeds 1843	2	0	7
Vitality of Seeds 1844	7	0	0
Marine Zoology of Cornwall	10	0	0
Physiological Action of Medicines	20	0	0
Statistics of Sickness and Mortality in York	20	0	0
Earthquake Shocks 1843	15	14	8
	£830	9	9

1846.

	£	s.	d.
British Association Catalogue of Stars 1844	211	15	0
Fossil Fishes of the London Clay	100	0	0
Computation of the Gaussian Constants for 1829	50	0	0
Maintaining the Establishment at Kew Observatory	146	16	7
Strength of Materials	60	0	0
Researches in Asphyxia	6	16	2
Examination of Fossil Shells	10	0	0
Vitality of Seeds 1844	2	15	10
Vitality of Seeds 1845	7	12	3
Marine Zoology of Cornwall	10	0	0
Marine Zoology of Britain	10	0	0
Exotic Anoplura 1844	25	0	0
Expenses attending Anemometers	11	7	6
Anemometers' Repairs	2	3	6
Atmospheric Waves	3	3	3
Captive Balloons 1844	8	19	3
Varieties of the Human Race 1844	7	6	3
Statistics of Sickness and Mortality in York	12	0	0
	£685	16	0

1847.

	£	s.	d.
Computation of the Gaussian Constants for 1829	50	0	0
Habits of Marine Animals	10	0	0
Physiological Action of Medicines	20	0	0
Marine Zoology of Cornwall	10	0	0
Atmospheric Waves	6	9	3
Vitality of Seeds	4	7	7
Maintaining the Establishment at Kew Observatory	107	8	6
	£208	5	4

1848.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	171	15	11
Atmospheric Waves	3	10	9
Vitality of Seeds	9	15	0
Completion of Catalogues of Stars	70	0	0
On Colouring Matters	5	0	0
On Growth of Plants	15	0	0
	£275	1	8

1849.

	£	s.	d.
Electrical Observations at Kew Observatory	50	0	0
Maintaining Establishment at ditto	76	2	5
Vitality of Seeds	5	8	1
On Growth of Plants	5	0	0
Registration of Periodical Phenomena	10	0	0
Bill on account of Anemometrical Observations	13	9	0
	£159	19	6

1850.

	£	s.	d.
Maintaining the Establishment at Kew Observatory	255	18	0
Transit of Earthquake Waves	50	0	0
Periodical Phenomena	15	0	0
Meteorological Instruments, Azores	25	0	0
	£345	18	0

	£	s.	d.
1851.			
Maintaining the Establishment at Kew Observatory (includes part of grant in 1849)	309	2	2
Theory of Heat	20	1	1
Periodical Phenomena of Animals and Plants	5	0	0
Vitality of Seeds	5	6	4
Influence of Solar Radiation	30	0	0
Ethnological Inquiries	12	0	0
Researches on Annelida	10	0	0
	£391	9	7
1852.			
Maintaining the Establishment at Kew Observatory (including balance of grant for 1850)	233	17	8
Experiments on the Conduction of Heat	5	2	9
Influence of Solar Radiations	20	0	0
Geological Map of Ireland	15	0	0
Researches on the British Annelida	10	0	0
Vitality of Seeds	10	6	2
Strength of Boiler Plates	10	0	0
	£304	6	7
1853.			
Maintaining the Establishment at Kew Observatory	165	0	0
Experiments on the Influence of Solar Radiation	15	0	0
Researches on the British Annelida	10	0	0
Dredging on the East Coast of Scotland	10	0	0
Ethnological Queries	5	0	0
	£205	0	0
1854.			
Maintaining the Establishment at Kew Observatory (including balance of former grant)	330	15	4
Investigations on Flax	11	0	0
Effects of Temperature on Wrought Iron	10	0	0
Registration of Periodical Phenomena	10	0	0
British Annelida	10	0	0
Vitality of Seeds	5	2	3
Conduction of Heat	4	2	0
	£380	19	7
1855.			
Maintaining the Establishment at Kew Observatory	425	0	0
Earthquake Movements	10	0	0
Physical Aspect of the Moon	11	8	5
Vitality of Seeds	10	7	11
Map of the World	15	0	0
Ethnological Queries	5	0	0
Dredging near Belfast	4	0	0
	£480	16	4
1856.			
Maintaining the Establishment at Kew Observatory:—			

	£	s.	d.
Strickland's Ornithological Synonyms	100	0	0
Dredging and Dredging Forms	9	13	9
Chemical Action of Light	20	0	0
Strength of Iron Plates	10	0	0
Registration of Periodical Phenomena	10	0	0
Propagation of Salmon	10	0	0
	£734	13	9
1857.			
Maintaining the Establishment at Kew Observatory	350	0	0
Earthquake Wave Experiments	40	0	0
Dredging near Belfast	10	0	0
Dredging on the West Coast of Scotland	10	0	0
Investigations into the Mollusca of California	10	0	0
Experiments on Flax	5	0	0
Natural History of Madagascar	20	0	0
Researches on British Annelida	25	0	0
Report on Natural Products imported into Liverpool	10	0	0
Artificial Propagation of Salmon	10	0	0
Temperature of Mines	7	8	0
Thermometers for Subterranean Observations	5	7	4
Life-Boats	5	0	0
	£507	15	4
1858.			
Maintaining the Establishment at Kew Observatory	500	0	0
Earthquake Wave Experiments	25	0	0
Dredging on the West Coast of Scotland	10	0	0
Dredging near Dublin	5	0	0
Vitality of Seeds	5	5	0
Dredging near Belfast	18	13	2
Report on the British Annelida	25	0	0
Experiments on the production of Heat by Motion in Fluids	20	0	
Report on the Natural Products imported into Scotland	10	0	0
	£618	18	2
1859.			
Maintaining the Establishment at Kew Observatory	500	0	0
Dredging near Dublin	15	0	0
Osteology of Birds	50	0	0
Irish Tunicata	5	0	0
Manure Experiments	20	0	0
British Medusidæ	5	0	0
Dredging Committee	5	0	0
Steam-vessels' Performance	5	0	0
Marine Fauna of South and West of Ireland	10	0	0
Photographic Chemistry	10	0	0
Lanarkshire Fossils	20	0	1
Balloon Ascents	39	11	0
	£684	11	1
1860.			
Maintaining the Establishment of Kew Observatory	500	0	0

	£	s.	d.
Inquiry into the Performance of Steam-vessels	124	0	0
Explorations in the Yellow Sandstone of Dura Den	20	0	0
Chemico-mechanical Analysis of Rocks and Minerals	25	0	0
Researches on the Growth of Plants	10	0	0
Researches on the Solubility of Salts	30	0	0
Researches on the Constituents of Manures	25	0	0
Balance of Captive Balloon Accounts	1	13	6
	£1241	7	0

1861.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	500	0	0
Earthquake Experiments	25	0	0
Dredging North and East Coasts of Scotland	23	0	0
Dredging Committee:— 1860 ......£50 0 0 1861 ...... £22 0 0	72	0	0
Excavations at Dura Den	20	0	0
Solubility of Salts	20	0	0
Steam-vessel Performance	150	0	0
Fossils of Lesmahago	15	0	0
Explorations at Uriconium	20	0	0
Chemical Alloys	20	0	0
Classified Index to the Transactions	100	0	0
Dredging in the Mersey and Dee	5	0	0
Dip Circle	30	0	0
Photoheliographic Observations	50	0	0
Prison Diet	20	0	0
Gauging of Water	10	0	0
Alpine Ascents	6	5	1
Constituents of Manures	25	0	0
	£1111	5	10

1862.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	500	0	0
Patent Laws	21	6	0
Mollusca of N.-W. America	10	0	0
Natural History by Mercantile Marine	5	0	0
Tidal Observations	25	0	0
Photoheliometer at Kew	40	0	0
Photographic Pictures of the Sun	150	0	0
Rocks of Donegal	25	0	0
Dredging Durham and Northumberland	25	0	0
Connexion of Storms	20	0	0
Dredging North-east Coast of Scotland	6	9	6
Ravages of Teredo	3	11	0
Standards of Electrical Resistance	50	0	0
Railway Accidents	10	0	0
Balloon Committee	200	0	0
Dredging Dublin Bay	10	0	0
Dredging the Mersey	5	0	0
Prison Diet	20	0	0
Gauging of Water	12	10	0
Steamships' Performance	150	0	0
Thermo-Electric Currents	5	0	0
	£1293	16	6

1863.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Balloon Committee deficiency	70	0	0
Balloon Ascents (other expenses)	25	0	0
Entozoa	25	0	0
Coal Fossils	20	0	0
Herrings	20	0	0
Granites of Donegal	5	0	0
Prison Diet	20	0	0
Vertical Atmospheric Movements	13	0	0
Dredging Shetland	50	0	0
Dredging North-east coast of Scotland	25	0	0
Dredging Northumberland and Durham	17	3	10
Dredging Committee superintendence	10	0	0
Steamship Performance	100	0	0
Balloon Committee	200	0	0
Carbon under pressure	10	0	0
Volcanic Temperature	100	0	0
Bromide of Ammonium	8	0	0
Electrical Standards	100	0	0
—— Construction and distribution	40	0	0
Luminous Meteors	17	0	0
Kew Additional Buildings for Photoheliograph	100	0	0
Thermo-Electricity	15	0	0
Analysis of Rocks	8	0	0
Hydroida	10	0	0
	£1608	3	10

1864.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Coal Fossils	20	0	0
Vertical Atmospheric Movements	20	0	0
Dredging Shetland	75	0	0
Dredging Northumberland	25	0	0
Balloon Committee	200	0	0
Carbon under pressure	10	0	0
Standards of Electric Resistance	100	0	0
Analysis of Rocks	10	0	0
Hydroida	10	0	0
Askham's Gift	50	0	0
Nitrite of Amyle	10	0	0
Nomenclature Committee	5	0	0
Rain-Gauges	19	15	8
Cast-Iron Investigation	20	0	0
Tidal Observations in the Humber	50	0	0
Spectral Rays	45	0	0
Luminous Meteors	20	0	0
	£1289	15	8

1865.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Balloon Committee	100	0	0
Hydroida	13	0	0

	£	s.	d.
Rain-Gauges	30	0	0
Tidal Observations in the Humber	6	8	0
Hexylic Compounds	20	0	0
Amyl Compounds	20	0	0
Irish Flora	25	0	0
American Mollusca	3	9	0
Organic Acids	20	0	0
Lingula Flags Excavation	10	0	0
Eurypterus	50	0	0
Electrical Standards	100	0	0
Malta Caves Researches	30	0	0
Oyster Breeding	25	0	0
Gibraltar Caves Researches	150	0	0
Kent's Hole Excavations	100	0	0
Moon's Surface Observations	35	0	0
Marine Fauna	25	0	0
Dredging Aberdeenshire	25	0	0
Dredging Channel Islands	50	0	0
Zoological Nomenclature	5	0	0
Resistance of Floating Bodies in Water	100	0	0
Bath Waters Analysis	8	10	0
Luminous Meteors	40	0	0
	£1591	7	10

1866.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Lunar Committee	64	13	4
Balloon Committee	50	0	0
Metrical Committee	50	0	0
British Rainfall	50	0	0
Kilkenny Coal Fields	16	0	0
Alum Bay Fossil Leaf-Bed	15	0	0
Luminous Meteors	50	0	0
Lingula Flags Excavation	20	0	0
Chemical Constitution of Cast Iron	50	0	0
Amyl Compounds	25	0	0
Electrical Standards	100	0	0
Malta Caves Exploration	30	0	0
Kent's Hole Exploration	200	0	0
Marine Fauna, &c., Devon and Cornwall	25	0	0
Dredging Aberdeenshire Coast	25	0	0
Dredging Hebrides Coast	50	0	0
Dredging the Mersey	5	0	0
Resistance of Floating Bodies in Water	50	0	0
Polycyanides of Organic Radicals	20	0	0
Rigor Mortis	10	0	0
Irish Annelida	15	0	0
Catalogue of Crania	50	0	0
Didine Birds of Mascarene Islands	50	0	0
Typical Crania Researches	30	0	0
Palestine Exploration Fund	100	0	0
	£1750	13	4

1867.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Meteorological Instruments, Palestine	50	0	0
Lunar Committee	120	0	0
Metrical Committee	30	0	0
Kent's Hole Explorations	100	0	0
Palestine Explorations	50	0	0
Insect Fauna, Palestine	30	0	0
British Rainfall	50	0	0
Kilkenny Coal Fields	25	0	0
Alum Bay Fossil Leaf-Bed	25	0	0
Luminous Meteors	50	0	0
Bournemouth, &c. Leaf-Beds	30	0	0
Dredging Shetland	75	0	0
Steamship Reports Condensation	100	0	0
Electrical Standards	100	0	0
Ethyle and Methyle series	25	0	0
Fossil Crustacea	25	0	0
Sound under Water	24	4	0
North Greenland Fauna	75	0	0
Do. Plant Beds	100	0	0
Iron and Steel Manufacture	25	0	0
Patent Laws	30	0	0
	£1739	4	0

1868.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Lunar Committee	120	0	0
Metrical Committee	50	0	0
Zoological Record	100	0	0
Kent's Hole Explorations	150	0	0
Steamship Performances	100	0	0
British Rainfall	50	0	0
Luminous Meteors	50	0	0
Organic Acids	60	0	0
Fossil Crustacea	25	0	0
Methyl series	25	0	0
Mercury and Bile	25	0	0
Organic remains in Limestone Rocks	25	0	0
Scottish Earthquakes	20	0	0
Fauna, Devon and Cornwall	30	0	0
British Fossil Corals	50	0	0
Bagshot Leaf-beds	50	0	0
Greenland Explorations	100	0	0
Fossil Flora	25	0	0
Tidal Observations	100	0	0
Underground Temperature	50	0	0
Spectroscopic investigations of Animal Substances	5	0	0
Secondary Reptiles, &c.	30	0	0
British Marine Invertebrate Fauna	100	0	0
	£1940	0	0

1869.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Lunar Committee	50	0	0
Metrical Committee	25	0	0
Zoological Record	100	0	0
Committee on Gases in Deep-well Water	25	0	0
British Rainfall	50	0	0
Thermal Conductivity of Iron, &c.	30	0	0
Kent's Hole Explorations	150	0	0
Steamship Performances	30	0	0

	£	s.	d.
Chemical Constitution of Cast Iron	80	0	0
Iron and Steel Manufacture	100	0	0
Methyl Series	30	0	0
Organic remains in Limestone Rocks	10	0	0
Earthquakes in Scotland	10	0	0
British Fossil Corals	50	0	0
Bagshot Leaf-Beds	30	0	0
Fossil Flora	25	0	0
Tidal Observations	100	0	0
Underground Temperature	30	0	0
Spectroscopic Investigations of Animal Substances	5	0	0
Organic Acids	12	0	0
Kiltorcan Fossils	20	0	0
Chemical Constitution and Physiological Action Relations	15	0	0
Mountain Limestone Fossils	25	0	0
Utilization of Sewage	10	0	0
Products of Digestion	10	0	0
	£1622	0	0

1870.

Maintaining the Establishment of Kew Observatory	600	0	0
Metrical Committee	25	0	0
Zoological Record	100	0	0
Committee on Marine Fauna	20	0	0
Ears in Fishes	10	0	0
Chemical nature of Cast Iron	80	0	0
Luminous Meteors	30	0	0
Heat in the Blood	15	0	0
British Rainfall	100	0	0
Thermal Conductivity of Iron &c.	20	0	0
British Fossil Corals	50	0	0
Kent's Hole Explorations	150	0	0
Scottish Earthquakes	4	0	0
Bagshot Leaf-Beds	15	0	0
Fossil Flora	25	0	0
Tidal Observations	100	0	0
Underground Temperature	50	0	0
Kiltorcan Quarries Fossils	20	0	0
Mountain Limestone Fossils	25	0	0
Utilization of Sewage	50	0	0
Organic Chemical Compounds	30	0	0
Onny River Sediment	3	0	0
Mechanical Equivalent of Heat	50	0	0
	£1572	0	0

1871.

	£	s.	d.
Maintaining the Establishment of Kew Observatory	600	0	0
Monthly Reports of Progress in Chemistry	100	0	0
Metrical Committee	25	0	0
Zoological Record	100	0	0
Thermal Equivalents of the Oxides of Chlorine	10	0	0
Tidal Observations	100	0	0
Fossil Flora	25	0	0
Luminous Meteors	30	0	0
British Fossil Corals	25	0	0
Heat in the Blood	7	2	6
British Rainfall	50	0	0
Kent's Hole Explorations	150	0	0
Fossil Crustacea	25	0	0
Methyl Compounds	25	0	0
Lunar Objects	20	0	0
Fossil Corals Sections, for Photographing	20	0	0
Bagshot Leaf-Beds	20	0	0
Moab Explorations	100	0	0
Gaussian Constants	40	0	0
	£1472	2	6

1872.

Maintaining the Establishment of Kew Observatory	300	0	0
Metrical Committee	75	0	0
Zoological Record	100	0	0
Tidal Committee	200	0	0
Carboniferous Corals	25	0	0
Organic Chemical Compounds	25	0	0
Exploration of Moab	100	0	0
Terato-Embryological Inquiries	10	0	0
Kent's Cavern Exploration	100	0	0
Luminous Meteors	20	0	0
Heat in the Blood	15	0	0
Fossil Crustacea	25	0	0
Fossil Elephants of Malta	25	0	0
Lunar Objects	20	0	0
Inverse Wave-Lengths	20	0	0
British Rainfall	100	0	0
Poisonous Substances Antagonism	10	0	0
Essential Oils, Chemical Constitution, &c.	40	0	0
Mathematical Tables	50	0	0
Thermal Conductivity of Metals	25	0	0
	£1285	0	0

1873.

Zoological Record	100	0	0
Chemistry Record	200	0	0
Tidal Committee	400	0	0
Sewage Committee	100	0	0
Kent's Cavern Exploration	150	0	0
Carboniferous Corals	25	0	0
Fossil Elephants	25	0	0
Wave-Lengths	150	0	0
British Rainfall	100	0	0
Essential Oils	30	0	0
Mathematical Tables	100	0	0
Gaussian Constants	10	0	0
Sub-Wealden Explorations	25	0	0
Underground Temperature	150	0	0
Settle Cave Exploration	50	0	0
Fossil Flora, Ireland	20	0	0
Timber Denudation and Rainfall	20	0	0
Luminous Meteors	30	0	0
	£1685	0	0

1874.	£	s.	d.
Zoological Record	100	0	0
Chemistry Record	100	0	0
Mathematical Tables	100	0	0
Elliptic Functions	100	0	0
Lightning Conductors	10	0	0
Thermal Conductivity of Rocks	10	0	0
Anthropological Instructions, &c.	50	0	0
Kent's Cavern Exploration	150	0	0
Luminous Meteors	30	0	0
Intestinal Secretions	15	0	0
British Rainfall	100	0	0
Essential Oils	10	0	0
Sub-Wealden Explorations	25	0	0
Settle Cave Exploration	50	0	0
Mauritius Meteorological Research	100	0	0
Magnetization of Iron	20	0	0
Marine Organisms	30	0	0
Fossils, North-west of Scotland	2	10	0
Physiological Action of Light	20	0	0
Trades Unions	25	0	0
Mountain-Limestone Corals	25	0	0
Erratic Blocks	10	0	0
Dredging, Durham and Yorkshire Coasts	28	5	0
High temperature of Bodies	30	0	0
Siemens's Pyrometer	3	6	0
Labyrinthodonts of Coal-Measures	7	15	0
	£1151	16	0

1875.	£	s.	d.
Elliptic Functions	100	0	0
Magnetization of Iron	20	0	0
British Rainfall	120	0	0
Luminous Meteors	30	0	0
Chemistry Record	100	0	0
Specific Volume of Liquids	25	0	0
Estimation of Potash and Phosphoric Acid	10	0	0
Isometric Cresols	20	0	0
Sub-Wealden Explorations	100	0	0
Kent's Cavern Exploration	100	0	0
Settle Cave Exploration	50	0	0
Earthquakes in Scotland	15	0	0
Underground Waters	10	0	0
Development of Myxinoid Fishes	20	0	0
Zoological Record	100	0	0
Instructions for Travellers	20	0	0
Intestinal Secretion	20	0	0
Palestine Exploration	100	0	0
	£960	0	0

General Meetings.

On Wednesday, August 25, at 8 P.M., in the Colston Hall, Professor John Tyndall, D.C.L., LL.D., F.R.S., President, resigned the office of President to Sir John Hawkshaw, C.E., F.R.S., F.G.S., who took the Chair, and delivered an Address, for which see page lxviii.

On Thursday, August 26, at 8 P.M., a Soirée took place in the Colston Hall.

On Friday, August 27, at 8.30 P.M., in the Colston Hall, W. Spottiswoode, Esq., M.A., LL.D., F.R.S., delivered a Discourse on "The Colours of Polarized Light."

On Saturday, August 28, at 7 P.M., in the Colston Hall, Dr. W. B. Carpenter, LL.D., F.R.S., delivered a Lecture, on "A Piece of Limestone," to the Working Classes of Bristol.

On Monday, August 30, at 8.30 P.M., in the Colston Hall, F. J. Bramwell, Esq., C.E., F.R.S., delivered a Discourse on "Railway Safety Appliances."

On Tuesday, August 31, at 8 P.M., a Soirée took place in the Colston Hall.

On Wednesday, September 1, at 2.30 P.M., the concluding General Meeting took place, when the Proceedings of the General Committee, and the Grants of Money for Scientific purposes, were explained to the Members.

The Meeting was then adjourned to Glasgow*.

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* The Meeting is appointed to take place on Wednesday, September 6, 1876.

ADDRESS

OF

SIR JOHN HAWKSHAW, C.E., F.R.S., F.G.S.,

PRESIDENT.

Gentlemen,—

To those on whom the British Association confers the honour of presiding over its meetings, the choice of a subject presents some difficulty.

The Presidents of Sections, at each annual meeting, give an account of what is new in their respective departments; and essays on science in general, though desirable and interesting in the earlier years of the Association, would be less appropriate to-day.

Past Presidents have already discoursed on many subjects, on things organic and inorganic, on the mind and on things perhaps beyond the reach of mind; and I have arrived at the conclusion that humbler themes will not be out of place on this occasion.

I propose in this Address to say something of a profession to which my lifetime has been devoted—a theme which cannot perhaps be expected to stand as high in your estimation as in my own, and I may have some difficulty in making it interesting; but I have chosen it because it is a subject I ought to understand better than any other. I propose to say something on its origin, its work, and kindred topics.

Rapid as has been the growth of knowledge and skill as applied to the art of the engineer during the last century, we must, if we would trace its origin, seek far back among the earliest evidences of civilization.

In early times, when settled communities were few and isolated, the opportunities for the interchange of knowledge were scanty or wanting altogether. Often the slowly accumulated results of the experience of the wisest heads and the most skilful hands of a community were lost on its downfall. Inventions of one period were lost and found again. Many a patient investigator has puzzled his brain in trying to solve a problem which had yielded to a more fortunate labourer in the same field some centuries before.

The ancient Egyptians had a knowledge of Metallurgy, much of which was lost during the years of decline which followed the golden age of their civilization. The art of casting bronze over iron was known to the Assyrians, though it has only lately been introduced into modern metallurgy; and patents were granted in 1609 for processes connected with the manufacture of glass which had been practised centuries before*. An inventor in the reign of Tiberius devised a method of producing flexible glass; but the manufactory of the artist was totally destroyed, we are told, in order to prevent the manufacture of copper, silver, and gold from becoming depreciated†.

Again and again engineers as well as others have made mistakes from not knowing what had been done by those who have gone before them. In the long discussion which took place as to the practicability of making the Suez Canal, an early objection was brought against it that there was a difference of 32½ feet between the level of the Red Sea and that of the Mediterranean. Laplace at once declared that such could not be the case, for the mean level of the sea was the same on all parts of the globe. Centuries before the time of Laplace the same objection had been raised to a project for joining the waters of these two seas. According to the old Greek and Roman historians, it was a fear of flooding Egypt with the waters of the Red Sea that made Darius, and in later times again Ptolemy, hesitate to open the canal between Suez and the Nile‡. Yet this canal was made, and was in use some centuries before the time of Darius.

Strabo§ tells us that the same objection, that the adjoining seas were of different levels, was made by his engineers to Demetrius‖, who wished to cut a canal through the Isthmus of Corinth some two thousand years ago. But Strabo¶ dismisses at once this idea of a difference of level, agreeing with Archimedes that the force of gravity spreads the sea equally over the earth.

When knowledge in its higher branches was confined to a few, those who possessed it were often called upon to perform many and various services for the communities to which they belonged; and we find mathematicians and astronomers, painters and sculptors, and priests called upon to perform the duties which now pertain to the profession of the architect and the engineer. And as soon as civilization had advanced so far as to admit of the accumulation of wealth and power, then kings and rulers sought to add to their glory while living by the erection of magnificent dwelling-places, and to provide for their aggrandizement after death by the construction of costly tombs and temples. Accordingly, we soon find men of ability and learning devoting a great part of their time to building and architecture, and the post of architect became one of honour and profit. In one of the most ancient quarries of Egypt a royal high architect of the dynasty of the Psammetici has left his pedigree sculptured on the rock, extending back for twenty-three generations, all of whom held the same post in succession in connexion with considerable sacerdotal offices *.

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* Layard's 'Nineveh and Babylon,' p. 191; Beckman's 'History of Inventions,' vol. ii. p. 85.

† Pliny, Nat. Hist. bk. xxxvi. cap. 66.

‡ Ibid. bk. vi. cap. 33.

§ Strabo, cap. iii. § 11.

‖ Demetrius I., King of Macedonia, died 283 B.C.

¶ Strabo, cap. iii. § 12.

As there were in these remote times officers whose duty it was to design and construct, so also there were those whose duty it was to maintain and repair the royal palaces and temples. In Assyria, 700 years before our era, as we know from a tablet found in the palace of Sennacherib by Mr. Smith, there was an officer whose title was the Master of Works. The tablet I allude to is inscribed with a petition to the king from an officer in charge of a palace, requesting that the Master of Works may be sent to attend to some repairs which were much needed at the time †.

Under the Roman Empire there was almost as great a division of labour in connexion with building and design as now exists. The great works of that period were executed and maintained by an army of officers and workmen, to each of whom special duties were assigned.

Passing by those early attempts at design and construction which supplied the mere wants of the individual and the household, it is to the East that we must turn if we would find the earliest works which display a knowledge of engineering. Whether the knowledge of engineering, if we may so call it, possessed by the people of Chaldæa and Babylonia was of native growth or was borrowed from Egypt is, perhaps, a question which cannot yet be answered. Both people were agricultural, dwelling on fertile plains intersected by great rivers, with a soil requiring water only to enable it to bring forth inexhaustible crops. Similar circumstances would create similar wants, and stimulate to action similar faculties to satisfy them. Apart from the question of priority of knowledge, we know that at a very early period, some four or five thousand years ago at least, there were men in Mesopotamia and Egypt who possessed considerable mechanical knowledge and no little skill in hydraulic engineering. Of the men themselves we know little: happily, works often remain when the names of those who conceived and executed them have long been forgotten.

It has been said that architecture had its origin not only in nature, but in religion; and if we regard the earliest works which required mechanical knowledge and skill, the same may be said of engineering. The largest stones were chosen for sacred buildings, that they might be more enduring as well as more imposing, thereby calling for improvement and invention of mechanical contrivances to assist in transporting and elevating them to the

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* Discoveries in Egypt, Ethiopia, &c., by Dr. Lepsius, 2nd edit. p. 318.

† Smith's (G.) 'Assyrian Discoveries,' 2nd edit. p. 414.

position they were to occupy; for the same reason the hardest and most costly materials were chosen, calling for further improvement in the metal forming the tools required to work them. The working of metals was further perfected in making images of the gods, and in adorning their shrines with the more precious and ornamental sorts.

The earliest buildings of stone to which we can assign a date, with any approach to accuracy, are the pyramids of Gizeh. To their builders they were sacred buildings, even more sacred than their temples or temple palaces. They were built to preserve the royal remains, until, after a lapse of 3000 years, which we have reason to believe was the period assigned, the spirit which had once animated the body should reenter it*. Although built 5000 years ago, the masonry of the Pyramids could not be surpassed in these days; all those who have seen and examined them, as I myself have done, agree in this; moreover, the design is perfect for the purpose for which they were intended, above all to endure. The building of pyramids in Egypt continued for some ten centuries, and from 60 to 70 still remain; but none are so admirably constructed as those of Gizeh. Still many contain enormous blocks of granite from 30 to 40 feet long, weighing more than 300 tons, and display the greatest ingenuity in the way in which the sepulchral chambers are constructed and concealed†.

The genius for dealing with large masses in building did not pass away with the pyramid-builders in Egypt; but their descendants continued to gain in mechanical knowledge, judging from the enormous blocks which they handled with precision. When the command of human labour was unlimited, the mere transport of such blocks as the statue of Rameses the Great, for instance, which weighed over 800 tons, need not so greatly excite our wonder; and we know how such blocks were moved from place to place, for it is shown on the wall-paintings of tombs of the period which still remain.

But as the weight of the mass to be moved is increased, it becomes no longer a mere question of providing force in the shape of human bone and muscle. In moving in the last century the block which now forms the base for the statue of Peter the Great at St. Petersburg, and which weighs 1200 tons, the necessary force could be applied, but great difficulty was experienced in supporting it, and the iron balls on which it was proposed to roll the block along were crushed, and a harder metal had to be substituted‡. To facilitate the transport of material, the Egyptians made solid causeways of granite from the Nile to the Pyramids; and in the opinion of Herodotus, who saw them, the causeways were more wonderful works than the Pyramids themselves§.

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* Fergusson's 'History of Architecture,' vol. i. p. 83; Wilkinson's 'Ancient Egyptians,' 2nd series, vol. ii. p. 444.

† Vyse's 'Pyramids of Gizeh,' vol. iii. pp. 16, 41, 45, 57.

‡ Rondelet's 'Traité de l'Art de Bâtir,' vol. i. p. 73.

§ Herodotus, bk. ii. cap. 124.

The Egyptians have left no record of how they accomplished a far more difficult operation than the mere transport of weight—that is, how they erected obelisks weighing upwards of 400 tons. Some of these obelisks must have been lifted vertically to place them in position, as they were by Fontana in Rome in later times, when the knowledge of mechanics, we know, was far advanced*.

The practice of using large blocks of stone either as monoliths or as forming parts of structures has existed from the earliest times in all parts of the world.

The Peruvians used blocks weighing from 15 to 20 tons, and fitted them with the greatest nicety in their cleverly designed fortifications†.

In India large blocks were used in bridges when the repugnance of Indian builders to the use of the arch rendered them necessary, or in temples, where, as in the Temple of the Sun at Orissa, stones weighing from 20 to 30 tons form part of the pyramidal roof at a height of from 70 to 80 feet from the ground‡. Even as late as the last century, Indians, without the aid of machinery, were using blocks of granite above 40 feet long for the door-posts of the gateway of Seringham, and roofing blocks of the same stone for a span of 21 feet§.

At Persepolis, in the striking remains of the palaces of Xerxes and Darius, more than one traveller has noted the great size of the stones, some of which are stated to be 55 feet long and 6 to 10 feet broad.

So in the Greek temples of Sicily, many of the blocks in the upper parts of the temples are from 10 to 20 tons weight.

The Romans, though they did not commonly use such large stones in their own constructions, carried off the largest obelisks from Egypt and erected them at Rome, where more are now to be found than remain in Egypt. In the temples of Baalbek, erected under Roman rule, perhaps the largest stones are to be found which have been used for building since the time of the Pharaohs. The terrace wall of one of the temples is composed of three courses of stones, none of which are less than 30 feet long; and one stone still lies in the quarry squared and ready for transport, which is 70 feet long and 14 feet square, and weighs upwards of 1135 tons, or nearly as much as one of the tubes of the Britannia Bridge.

I have not mentioned dolmens and menhirs, rude unhewn stones often weighing from 30 to 40 tons, which are found from Ireland to India, and from Scandinavia to the Atlas, in Africa. To transport and erect such rude masses required little mechanical knowledge or skill, and the operation has excited more wonder than it deserves. Moreover, Fergusson has gone far to show that the date assigned to many of them hitherto has been far too remote; most, and possibly all, of those in northern and western Europe having been erected since the time of the Roman occupation. And to this day the same author shows that menhirs, single stones often weighing over 20 tons, are erected by hill-tribes of India in close proximity to stone buildings of elaborate design and finished execution, erected by another race of men*.

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* For the obelisk erected at Arles in the year 1676, see Rondelet's 'L'Art de Bâtir,' vol. i. p. 48. Its weight was nearly 200 tons, and it was suspended vertically by eight ships' masts.

† Fergusson's 'History of Architecture,' vol. ii. p. 779; Squier, Peru, p. 24.

‡ The temple of the Sun was built 1237-1282 A.D. (Hunter's 'Orissa,' vol. i. pp. 288, 297).

§ Fergusson's 'Rude Stone Monuments,' p. 96.

For whatever purpose these vast stones were selected (whether to enhance the value or to prolong the endurance of the buildings of which they formed a part), the tax on the ingenuity of those who moved and placed them must have tended to advance the knowledge of mechanical appliances.

The ancient Assyrians and Egyptians had possibly more knowledge of mechanical appliances than they are generally credited with. In the wall paintings and sculptures which show their mode of transporting large blocks of stone, the lever is the only mechanical power represented, and which they appear to have used in such operations; nor ought we to expect to find any other used, for, where the supply of human labour was unlimited, the most expeditious mode of dragging a heavy weight along would be by human power; to have applied pulleys and capstans, such as would now be employed in similar undertakings, would have been mere waste of time. In some countries, even now, where manual labour is more plentiful than mechanical appliances, large numbers of men are employed to transport heavy weights, and do the work in less time than it could be done with all our modern mechanical appliances. In other operations, such as raising obelisks or the large stones used in their temple palaces, where human labour could not be applied to such advantage, it is quite possible that the Egyptians used mechanical aids. On one of the carved slabs which formed part of the wall-panelling of the palace of Sardanapalus, which was built about 930 years before our era, a single pulley is clearly shown, by which a man is in the act of raising a bucket —probably drawing water from a well†.

It has sometimes been questioned whether the Egyptians had a knowledge of steel. It seems unreasonable to deny them this knowledge. Iron was known at the earliest times of which we have any record. It is often mentioned in the Bible and in Homer; it is shown in the early paintings on the walls of the tombs at Thebes, where butchers are represented as sharpening their knives on pieces of metal coloured blue, which were most probably pieces of steel‡. Iron has been found in quantity in the ruined palaces of Assyria; and in the inscriptions of that country fetters are spoken of as having been made of iron, which is also so mentioned in connexion with other metals as to lead to the supposition that it was regarded as a base and common metal.

* Fergusson's 'Rude Stone Monuments,' pp. 461-465.

† Layard's 'Nineveh and its Remains,' vol. ii. p. 31.

‡ Wilkinson's 'Ancient Egyptians,' vol. iii. p. 247.

Moreover, in the Great Pyramid a piece of iron was found in a place where it must have lain for 5000 years*. The tendency of iron to oxidize must render its preservation for any long period rare and exceptional. The quality of iron which is now made by the native races of Africa and India is that which is known as wrought iron; in ancient times, Dr. Percy says the iron which was made was always wrought iron. It is very nearly pure iron, and a very small addition of carbon would convert it into steel. Dr. Percy says the extraction of good malleable iron directly from the ore "requires a degree of skill very far inferior to that which is implied in the manufacture of bronze"†. And there is no great secret in making steel; the natives of India now make excellent steel in the most primitive way, which they have practised from time immemorial. When steel is to be made, the proportion of charcoal used with a given quantity of ore is somewhat larger, and the blast is applied more slowly than when wrought iron is the metal required‡. Thus a vigorous native working the bellows of skin would make wrought iron where a lazy one would have made steel. The only apparatus required for the manufacture of the finest steel from iron ore is some clay for making a small furnace four feet high and from one to two broad, some charcoal for fuel, and a skin with a bamboo tuyere for creating the blast.

The supply of iron in India as early as the fourth and fifth centuries seems to have been unlimited. The iron pillar of Delhi is a remarkable work for such an early period. It is a single piece of wrought iron 50 feet in length, and it weighs not less than 17 tons§. How the Indians forged this large mass of iron and other heavy pieces which their distrust of the arch led them to use in the construction of roofs, we do not know. In the temples of Orissa iron was used in large masses as beams or girders in roof-work in the thirteenth century‖.

The influence of the discovery of iron on the progress of art and science cannot be over-estimated. India well repaid any advantage which she may have derived from the early civilized communities of the West if she were the first to supply them with iron and steel.

An interesting social problem is afforded by a comparison of the relative conditions of India and this country at the present time. India, from thirty to forty centuries ago, was skilled in the manufacture of iron and cotton goods, manufactures which in less than a century have done so much for this country. It is true that in India coal is not so abundant or so universally distributed as in this country. Yet, if we look still further to the East, China had probably knowledge of the use of metals as soon as India, and, moreover, had a boundless store of iron and coal. Baron Richthofen, who has visited and described some of the coal-fields of China, believes that one province alone, that of Southern Shansi, could supply the world at its present rate of consumption for several thousand years. The coal is near the surface, and iron abounds with it. Marco Polo tells us that coal was universally used as fuel in the parts of China which he visited towards the end of the fourteenth century, and from other sources we have reason to believe it was used there as fuel 2000 years ago. But what progress has China made in the last ten centuries? A great future is undoubtedly in store for that country; but can the race who now dwell there develop its resources, or must they await the aid of an Aryan race? Or is any thing more necessary than a change of institutions, which might come unexpectedly, as in Japan?

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* Vyse's 'Pyramids of Gizeh,' vol. i. p. 275.

† Percy's 'Iron and Steel,' p. 873. ‡ Ibid. p. 259.

§ Fergusson's 'History of Architecture,' vol. ii. p. 460; and 'Rude Stone Monuments,' pp. 481-3. Cunningham's 'Archæological Survey of India,' vol. i. p. 169.

‖ Hunter's 'Orissa,' vol. i. p. 298.

The art of extracting metals from the ore was practised at a very early date in this country. The existence long ago of tin-mines in Cornwall, so often spoken of by classical writers, is well known to all. That iron was also extracted from the ore by the ancient Britons is most probable, as it was largely used for many purposes by them before the Roman conquest. The Romans worked iron extensively in the Weald of Kent, as we assume from the large heaps of slag containing Roman coins which still remain there. The Romans always availed themselves of the mineral wealth of the countries which they conquered, and their mining-operations were often carried out on the largest scale, as in Spain, for instance, where as many as forty thousand miners were regularly employed in the mines at New Carthage*.

Coal, which was used for ordinary purposes in England as early as the ninth century, does not appear to have been largely used for iron-smelting until the eighteenth century, though a patent was granted for smelting iron with coal in the year 1611†. The use of charcoal for that purpose was not given up until the beginning of this century, since which period an enormous increase in the mining and metallurgical industries has taken place; the quantity of coal raised in the United Kingdom in 1873 having amounted to 127 million tons, and the quantity of pig iron to upwards of 6½ million tons.

The early building energy of the world was chiefly spent on the erection of tombs, temples, and palaces.

While in Egypt, as we have seen, the art of building in stone had 5000 years ago reached the greatest perfection, so in Mesopotamia the art of building with brick, the only available material in that country, was in an equally advanced state some ten centuries later. That buildings of such a material have lasted to this day shows how well the work was done; their ruinous condition even now is owing to their having served as quarries for the last three or four thousand years, so that the name of Nebuchadnezzar, apparently one of the greatest builders of ancient times, is as common on the bricks of many modern towns in Persia as it was in old times in Babylon. The labour required to construct the brick temples and palaces of Chaldæa and Assyria must have been enormous. The mound of Koyunjik alone contained 14½ million tons, and represents the labour of 10,000 men for twelve years. The palace of Sennacherib, which stood on this mound, was probably the largest ever built by any one monarch, containing as it did more than two miles of walls, panelled with sculptured alabaster slabs, and twenty-seven portals, formed by colossal bulls and sphinxes*.

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* Strabo, bk. iii. cap. ii. § 10.

† Percy's 'Iron and Steel,' p. 882.

The pyramidal temples of Chaldæa are not less remarkable for the labour bestowed on them, and far surpass the buildings of Assyria in the excellence of their brickwork.

The practice of building great pyramidal temples seems to have passed eastwards to India and Burmah, where it appears in buildings of a later date, in Buddhist topes and pagodas—marvels of skill in masonry, and far surpassing the old brick mounds of Chaldæa in richness of design and in workmanship. Even so late as this century a king of Burmah began to build a brick temple of the old type, the largest building, according to Fergusson, which has been attempted since the Pyramids†.

The mere magnitude of many of these works is not so wonderful when we take into account the abundance of labour which those rulers could command. Countries were depopulated and their inhabitants carried off and made to labour for the conquerors. The inscriptions of Assyria describe minutely the spoils of war and the number of captives; and in Egypt we have frequent mention made of works being executed by the labour of captive peoples. Herodotus tells us that as many as 360,000 men were employed in building one palace for Sennacherib‡. At the same time, it must not be forgotten that the very character of the multitude would demand from some one the skill and brain to organize and direct, to design and plan the work.

It would be surprising if men who were capable of undertaking and successfully completing unproductive works of such magnitude did not also employ their powers on works of a more useful class. Traces still remain of such works; enough to show, when compared with the scanty records of the times which have come down to us, that the prosperity of such countries as Egypt and Mesopotamia was not wholly dependent on war and conquest, but that the reverse was more likely the case, and that the natural capabilities of those countries were greatly enlarged by the construction of useful works of such magnitude as to equal, if not in some cases surpass, those of modern times.

Egypt was probably far better irrigated in the days of the Pharaohs than it is now. To those unacquainted with the difficulties which must be met with and overcome before a successful system of irrigation can be carried out, even in countries in which the physical conditions are favourable, it may appear that nothing more is required than an adequate supply of unskilled labour. Far more than this was required: the Egyptians had some knowledge of surveying, for Eustathius says they recorded their marches on maps *; but such knowledge was probably in those days very limited, and it required no ordinary grasp of mind to see the utility of such extensive works as were carried out in Egypt and Mesopotamia, and, having seen the utility, to successfully design and execute them. To cite one in Egypt—Lake Mœris, of which the remains have been explored by M. Linant, was a reservoir made by one of the Pharaohs, and supplied by the flood-waters of the Nile. It was 150 square miles in extent, and was retained by a bank or dam 60 yards wide and 10 high, which can be traced for a distance of thirteen miles. This reservoir was capable of irrigating 1200 square miles of country †. No work of this class has been undertaken on so vast a scale since, even in these days of great works.

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* Layard's 'Nineveh and Babylon,' p. 589.

† Fergusson's 'History of Architecture,' vol. ii. p. 523.

‡ Rawlinson's 'Herodotus,' vol. i. p. 389, 2nd edit.

The prosperity of Egypt was in so great a measure dependent on its great river, that we should expect that the Egyptians, a people so advanced in art and science, would at an early period have made themselves acquainted with its *régime*. We know that they carefully registered the height of the annual rise of its waters; such registers still remain inscribed on the rocks on the banks of the Nile, with the name of the king in whose reign they were made ‡. The people of Mesopotamia were equally observant of the *régime* of their great rivers, and took advantage in designing their canals of the different periods in the rising of the waters of the Tigris and Euphrates. A special officer was appointed in Babylon, whose duty it was to measure the rise of the river; and he is mentioned in an inscription found in the ruins of that city, as recording the height of the water in the temple of Bel §. The Assyrians, who had a far more difficult country to deal with, owing to its rocky and uneven surface, showed even greater skill than the Babylonians in forming their canals, tunnelling through rock, and building dams of masonry across the Euphrates. While the greater number of these canals in Egypt and Mesopotamia were made for the purpose of irrigation, others seem to have been made to serve at the same time for navigation. Such was the canal which effected a junction between the Mediterranean and the Red Sea, which was a remarkable work, having regard to the requirements of the age in which it was made. Its length was about 80 miles; its width admitted of two triremes passing one another ‖. At least one of the navigable canals of Babylonia, attributed to Nebuchadnezzar, can compare in extent with any work of later times. I believe Sir H. Rawlinson has traced the canal to which I allude throughout the greater part of its course, from Hit on the Euphrates to the Persian Gulf, a distance of between four and five hundred miles*. It is a proof of the estimation in which such works were held in Babylonia and Assyria, that, among the titles of the god Vul were those of "Lord of Canals" and "The Establisher of Irrigation Works"†.

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* Rawlinson's 'Herodotus,' vol. ii. p. 278, 2nd edit.

† M. Linant's 'Mémoire sur le lac Mœris.'

‡ Lepsius's 'Discoveries in Egypt, &c.,' p. 268.

§ Smith's 'Assyrian Discoveries,' pp. 395–397, 2nd edit.

‖ Herodotus, bk. ii. cap. clviii.

The springs of knowledge which had flowed so long in Babylonia and Assyria were dried up at an early period. With the fall of Babylon and destruction of Nineveh the settled population of the fertile plains around them disappeared; and that which was desert before man led the waters over it became desert again, affording a wide field for, and one well worthy of, the labours of engineers to come.

Such was not the case with Egypt. Long after the period of its greatest prosperity was reached, it remained the fountain head from whence knowledge flowed to Greece and Rome. The philosophers of Greece and those who, like Archimedes, were possessed of the best mechanical knowledge of the time, repaired to Egypt to study and there obtained much of their knowledge.

Greatly as Greece and Rome were indebted to Egypt, it will probably be found, as the inscribed tablets met with in the mounds of Assyria and Chaldæa are deciphered, that the later civilizations owe, if not more, at least as much, to those countries as to Egypt. This is the opinion of Mr. Smith, who, in his work describing his recent interesting discoveries in the East, says that the classical nations "borrowed far more from the valley of the Euphrates than that of the Nile"‡.

In the science of astronomy, which in these days is making such marvellous discoveries, Chaldæa was undoubtedly preeminent. Among the many relics of these ancient peoples which Mr. Smith has recently brought to this country is a portion of a metal astrolabe from the palace of Sennacherib, and a tablet on which is recorded the division of the heavens according to the four seasons, and the rule for regulating the intercalary month of the year. Not only did the Chaldæans map out the heavens and arrange the stars, but they traced the motion of the planets, and observed the appearance of comets; they fixed the signs of the zodiac, and they studied the sun and moon and the periods of eclipses§.

But to return to that branch of knowledge to which I wish more particularly to draw your attention, as it grew and spread from East to West, from Asia over Europe. Of all nations of Europe, the Greeks were most intimately connected with the civilization of the East. A maritime people by the nature of the land they lived in, colonization followed as a matter of course on the tracks of their trading-vessels; and thus, more than any other people, they helped to spread Eastern knowledge along the shores of the Mediterranean and throughout the south of Europe.

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* Rawlinson's 'Herodotus,' vol. i. p. 420, 2nd edit.

† Ibid. p. 498.

‡ Smith's (G.) 'Assyrian Discoveries,' p. 451, 2nd edit.

§ Ibid.

The early constructive works of Greece, till about the seventh century B.C., form a strong contrast to those of its more prosperous days. Commonly called Pelasgian, they are more remarkable as engineering works than admirable as those which followed them were for architectural beauty. Walls of huge unshapely stones (admirably fitted together, however), tunnels, and bridges characterize this period. In Greece, during the few and glorious centuries which followed, the one aim in all construction was to please the eye, to gratify the sense of beauty; and in no age was that aim more thoroughly and satisfactorily attained.

In these days, when sanitary questions attract each year more attention, we may call to mind that twenty-three centuries ago the city of Agrigentum possessed a system of sewers, which, on account of their large size, were thought worthy of mention by Diodorus*. This is not, however, the first record of towns being drained; the well-known Cloaca Maxima, which formed part of the drainage system of Rome, was built some two centuries earlier, and great vaulted drains passed beneath the palace mounds of unburnt brick at Nimroud and Babylon; and possibly we owe the preservation of many of the interesting remains found in the brick mounds of Chaldæa to the very elaborate system of pipe drainage discovered in them and described by Loftus†.

Whilst Pelasgian art was being superseded in Greece, the city of Rome was founded in the eighth century before our era; and Etruscan art in Italy, like the Pelasgian art in Greece, was slowly merged in that of an Aryan race. The Etruscans, like the Pelasgians and the old Egyptians, were Turanians, and remarkable for their purely constructive or engineering works. Their city walls far surpass those of any other ancient race, and their drainage works and tunnels are most remarkable.

The only age which can compare with the present one in the rapid extension of utilitarian works over the face of the civilized world is that during which the Romans, an Aryan race, as we are, were in power. As Fergusson has said, the mission of the Aryan races appears to be to pervade the world with useful and industrial arts. That the Romans adorned their bridges, their aqueducts, and their roads, that with a sound knowledge of construction they frequently made it subservient to decoration, was partly owing to the mixture of Etruscan or Turanian blood in their veins, and partly to their great wealth, which made them disregard cost in their construction, and to their love of display.

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* Agrigentum was a celebrated Greek city, founded B.C. 582, population 200,000 (Diodorus, 406 B.C.), drained by Phœax, who lived B.C. 480.

† Rawlinson's 'Five Ancient Monarchies,' vol. i. pp. 89, 90, 2nd. edit.

It would be impossible for me to do justice to even a small part of the engineering works which have survived fourteen centuries of strife, and remain to this day as monuments of the skill, the energy, and ability of the great Roman people. Fortunately their works are more accessible than those of which I have hitherto spoken, and many of you are probably already familiar with them.

Conquerors of the greater part of the civilized world, the admirable organization of the Romans enabled them to make good use of the unbounded resources which were at their disposal. Yet, while the capital was enriched, the development of the resources of the most distant provinces of the empire was never neglected.

War, with all its attendant evils, has often indirectly benefited mankind. In the long sieges which took place during the old wars of Greece and Rome, the inventive power of man was taxed to the utmost to provide machines for attack and defence. The ablest mathematicians and philosophers were pressed into the service, and helped to turn the scale in favour of their employers. The world has to regret the loss of more than one, who, like Archimedes, fell slain by the soldiery while applying the best scientific knowledge of the day to devising means of defence during the siege*. In these days, too, science owes much to the labours of engineers and able men, whose time is spent in making and improving guns, the materials composing them, and armour plates to resist them, or in studying the motion of ships of war in a seaway.

The necessity for roads and bridges for military purposes has led to their being made where the necessary stimulus from other causes was wanting; and so means of communication, and the interchange of commodities, so essential to the prosperity of any community, have thus been provided. Such was the case under the Roman Empire. So, too, in later times, the ambition of Napoleon covered France and the countries subject to her with an admirable system of military roads. At the same time, we must do Napoleon the justice of saying that his genius and foresight gave a great impetus to the construction of all works favourable to commercial progress. So, again, in this country it was the rebellion of 1745, and the want felt of roads for military purposes, which first led to the construction of a system of roads in it unequalled since the time of the Roman occupation. And lastly, in India, in Germany, and in Russia, more than one example could be pointed out where industry will benefit by railways which have originated in military precautions rather than in commercial requirements.

But to return to Rome. Roads followed the tracks of her legions into the most distant provinces of the empire. Three hundred and seventy-two great roads are enumerated, together more than 48,000 miles in length, according to the itinerary of Antoninus.

The water supply of Rome during the first century of our era would suffice for a population of seven millions, supplied at the rate at which the present population of London is supplied. This water was conveyed to Rome by nine aqueducts; and in later years the supply was increased by the construction of five more aqueducts. Three of the old aqueducts have sufficed to supply the wants of the city in modern times. These aqueducts of Rome are to be numbered among her grandest engineering works *. Time will not admit of my saying any thing about her harbour works and bridges, her basilicas and baths, and numerous other works in Europe, in Asia, and in Africa. Not only were these works executed in a substantial and perfect manner, but they were maintained by an efficient staff of men divided into bodies, each having their special duties to perform. The highest officers of state superintended the construction of works, were proud to have their names associated with them, and constructed extensive works at their own expense.

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* Archimedes, B.C. 287–212; killed at the siege of Syracuse by the Roman soldiers.

Progress in Europe stopped with the fall of the Roman Empire. In the fourth and succeeding centuries the barbarian hordes of Western Asia, people who felt no want of roads and bridges, swept over Europe to plunder and destroy.

With the seventh century began the rise of the Mohammedan power, and a partial return to conditions apparently more favourable to the progress of industrial art, when widespread lands were again united under the sway of powerful rulers†. Science owes much to Arab scholars, who kept and handed on to us the knowledge acquired so slowly in ancient times, and much of which would have been lost but for them. Still, few useful works remain to mark the supremacy of the Mohammedan power at all comparable to those of the age which preceded its rise.

A great building age began in Europe in the tenth century, and lasted through the thirteenth. It was during this period that these great ecclesiastical buildings were erected, which are not more remarkable for artistic excellence than for boldness in design.

While the building of cathedrals progressed on all sides in Europe, works of a utilitarian character, which concern the engineer, did not receive much encouragement, excepting perhaps in Italy.

From the twelfth to the thirteenth centuries, with the revival of the arts and sciences in the Italian republics, many important works were undertaken for the improvement of the rivers and harbours of Italy. In 1481 canal-locks were first used; and some of the earliest of which we have record were erected by Leonardo da Vinci, who would be remembered as a skilful engineer had he not left other greater and more attractive works to claim the homage of posterity.

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* Total length 250 miles; 50 on arches, 200 underground.

† "Under the last of the house of Ommiyah (750 A.D.) one command was obeyed almost along the whole diameter of the known world, from the banks of the Sihon to the utmost promontory of Portugal."—*Hallam's Middle Ages*, vol. ii. p. 120, 2nd edit.

The great use that has since been made of this simple means of transferring floating vessels from one water-level to another, in connexion not only with inland navigation, but in all the great ports and harbours of the world, renders it all the more deserving of remark.

In India, under the Moguls, irrigation works, for which they had a natural aptitude, were carried on during these centuries with vigour, and more than one emperor is noted for the numerous great works of this nature which he carried out. If the native records can be trusted, the number of hydraulic works undertaken by some rulers is surprising. Tradition relates that one king who reigned in Orissa in the twelfth century made one million tanks or reservoirs, besides building sixty temples and erecting numerous other works[*].

In India, the frequent overflow of the great rivers, and the periodical droughts, which rendered irrigation necessary, led to extensive protective works being undertaken at an early period; but as these works have been maintained by successive rulers, Mogul and Mohammedan, until recent times, and have not been left for our inspection, deserted and useless for 3,000 years or more, as is often the case in Egypt and Mesopotamia, there is more difficulty in ascertaining the date of such works in India.

Works of irrigation were among the earliest attempts at engineering undertaken by the least civilized inhabitants in all parts of the world. Even in Australia, where savages are found as low as any in the scale of civilization, traces of irrigation works have been found; these works, however, must be taken to show that the natives were once somewhat more civilized than we now find them. In Feejee, our new possession, the natives occasionally irrigate their land[†], and have executed a work of a higher class, a canal some two miles long and sixty feet wide, to shorten the distance passed over by their canoes[‡]. The natives of New Caledonia irrigate their fields with great skill[§]. In Peru, the Incas excelled in irrigation as in other great and useful works, and constructed most admirable underground conduits of masonry for the purpose of increasing the fertility of the land[||].

It is frequently easier to lead water where it is wanted than to check its irruption into places where its presence is an evil, often a disaster. For centuries the existence of a large part of Holland has been dependent on the skill of man. How soon he began in that country to contest with the sea the possession of the land we do not know; but early in the twelfth century dykes were constructed to keep back the ocean. As the prosperity of the country increased with the great extension of its commerce, and land became more valuable and necessary for an increasing population, very extensive works were undertaken. Land was reclaimed from the sea, canals were cut, and machines were designed for lifting water. To the practical knowledge acquired by the Dutch, whose method of carrying out hydraulic works is original and of native growth, much of the knowledge of the present day in embanking, and draining, and canal-making is due. The North-Holland Canal* was the largest navigable canal in existence until the Suez Canal was completed; and the Dutch have just now nearly finished making a sea-canal from Amsterdam to the North Sea, which, though not equal to the Suez Canal in length, will be as great in width and depth, and involves perhaps larger and more important works of art. This country was for many years beholden to the Dutch for help in carrying out hydraulic works. In the seventeenth century much fen land in the eastern counties was drained by Dutch labour, directed by Dutch engineers, among whom Sir Cornelius Vermuyden, an old campaigner of the Thirty Years' War and a colonel of horse under Cromwell, is the most noted.

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[*] King Bhim Deo, A.D. 1174, 60 temples, 10 bridges, 40 wells stone-cased, 152 landing-stairs, and one million tanks (Hunter's 'Orissa,' vol. i. p. 100).

[†] Erskine's 'Western Pacific,' p. 171.

[‡] Seeman, p. 82.

[§] Erskine's 'Western Pacific,' p. 355.

[||] Markham's 'Cieza' (note), p. 236.

While the Dutch were acquiring practical knowledge in dealing with water, and we in Britain among others were benefiting by their experience, the disastrous results which ensued from the inundations caused by the Italian rivers of the Alps gave a new importance to the science of hydraulics. Some of the greatest philosophers of the seventeenth century (among them Torricelli, a pupil of Galileo †) were called upon to advise and to superintend engineering works; nor did they confine themselves to the construction of preventive works, but thoroughly investigated the conditions pertaining to fluids at rest or in motion, and gave to the world a valuable series of works on hydraulics and hydraulic engineering, which form the basis of our knowledge of these subjects at the present day.

Some of the best scientific works (prior to the nineteenth century) on engineering subjects we owe to Italian and French writers. The writings of Belidor, an officer of artillery in France in the seventeenth century, who did not, however, confine himself to military subjects, drew attention to engineering questions. Not long after their appearance, the Ponts et Chaussées ‡ were established, which has maintained ever since a body of able men specially educated for and devoted to the prosecution of industrial works.

The impulse given to road-making in the early part of the last century soon extended to canals and means for facilitating locomotion and transport generally. Tramways were used in connexion with mines at least as early as the middle of the seventeenth century; but the rails were, in those days, of wood. The first iron rails are said to have been laid in this country as early as 1738, after which time their use was gradually extended, until it became general in mining-districts.

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* North-Holland Canal, finished in 1825.

† Galileo, b. 1564; Torricelli, b. 1608.

‡ Ponts et Chaussées, established 1720.

By the beginning of this century the great ports of England were connected by a system of canals; and new harbour works became necessary and were provided to accommodate the increase of commerce and trade, which improved means of internal transport had rendered possible. It was in the construction of these works that our Brindley and Smeaton, Telford and Rennie, and other engineers of their time did so much.

But it was not until the steam-engine, improved and almost created by the illustrious Watt, became such a potent instrument, that engineering works to the extent they have since been carried out became possible or necessary. It gave mankind no new faculty; but it at once set his other faculties on an eminence, from which the extent of his future operations became almost unlimited.

Water-mills, wind-mills, and horse-machines were in most cases superseded. Deep mines, before only accessible by adits and water-levels, could at once be reached with ease and economy. Lakes and fens which, but for the steam-engine, would have been left untouched, were drained and cultivated.

The slow and laborious toil of hands and fingers, bone and sinew, was turned to other employments, where, aided by ingenious mechanical contrivances, the produce of one pair of hands was multiplied a thousandfold, and their cunning extended until results marvellous, if you consider them, were attained. Since the time of Watt the steam-engine has exerted a power, made conquests, and increased and multiplied the material interests of this globe to an extent which it is scarcely possible to realize.

But while Watt has gained a world-wide, well-earned fame, the names of those men who have provided the machines to utilize the energies of the steam-engine are too often forgotten. Of their inventions the majority of mankind know little. They worked silently at home, in the mill, or in the factory, observed by few. Indeed, in most cases, these silent workers had no wish to expose their work to public gaze. Were it not so, the factory and the mill are not places where people go to take the air. How long in the silent night the inventors of these machines sat and pondered; how often they had to cast aside some long-sought mechanical movement and seek another and a better arrangement of parts, none but themselves could ever know. They were unseen workers, who succeeded by rare genius, long patience, and indomitable perseverance.

More ingenuity and creative mechanical genius is perhaps displayed in machines used for the manufacture of textile fabrics than by those used in any other industry. It was not until late in historical times that the manufacture of such fabrics became established on a large scale in Europe. Although in

China man was clothed in silk long ago, and although Confucius, in a work written 2,300 years ago, orders with the greatest minuteness the rules to be observed in the production and manufacture of silk, yet it was worth nearly its weight in gold in Europe in the time of Aurelian, whose empress had to forego the luxury of a silk gown on account of its cost*. Through Constantinople and Italy the manufacture passed slowly westwards, and was not established in France until the sixteenth century, and arrived at a still later period in this country.

So cotton, of which the manufacture in India dates from before historical times, had scarcely by the Christian era reached Persia and Egypt. Spain in the tenth and Italy in the fourteenth century manufactured it, but Manchester, which is now the great metropolis of the trade, not until the latter half of the seventeenth century.

Linen was worn by the old Egyptians, and some of their linen mummy-cloths surpass in fineness any linen fabrics made in later days†. The Babylonians wore linen also and wool, and obtained a widespread fame for skill in workmanship and beauty in design.

In this country wool long formed the staple for clothing. Silk was the first rival, but its costliness placed it beyond the reach of the many. To introduce a new material or improved machine into this or other countries a century or more ago was no light undertaking. Inventors and would-be benefactors alike ran the risk of loss of life. Loud was the outcry made in the early part of the eighteenth century against the introduction of Indian cottons and Dutch calicoes.

Until 1738, in which year improvements in spinning-machinery were begun, each thread of worsted or cotton wool had been spun between the fingers in this and all other countries. Wyatt, in 1738, invented spinning-rollers instead of fingers, and his invention was further improved by Arkwright. In 1770 Hargreaves patented the spinning-jenny, and Crompton the mule in 1775, a machine which combined the advantages of the frames of both Hargreaves and Arkwright. In less than a century after the first invention by Wyatt, double mules were working in Manchester with over 2,000 spindles.

Improvements in machines for weaving were begun at an earlier date. In 1579 a ribbon-loom is said to have been invented at Dantzic, by which from four to six pieces could be woven at one time; but the machine was destroyed and the inventor lost his life‡. In 1800 Jacquard's most ingenious invention was brought into use, which, by a simple mechanical operation, determines the movements of the threads which form the pattern in weaving. But the greatest discovery in the art of weaving was wrought by Cartwright's discovery of the power-loom, which led eventually to the substitution of steam for manual labour, and enabled a boy with a steam-loom to do fifteen times the work of a man with a hand-loom.

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* Manufacture of silk brought from China to Constantinople A.D. 522.

† Wilkinson's 'Ancient Egyptians;' Pliny, bk. xix. c. ii.

‡ Beckman's 'History of Inventions,' vol. ii. p. 528.

For complex ingenuity few machines will compare with those used in the manufacture of lace and bobbin net. Hammond, in 1768, attempted to adapt the stocking-frame to this manufacture, which had hitherto been conducted by hand. It remained for John Heathcote to complete the adaptation in 1809, and to revolutionize this branch of industry, reducing the cost of its produce to one-fortieth of what the cost had been before Heathcote's improvements were effected.

Most of these ingenious machines were in use before Watt's genius gave the world a new motive power in the steam-engine; and, had the steam-engine never been perfected, they would still have enormously increased the productive power of mankind. Water-power was applied to many of them; in the first silk-thread mill erected at Derby in 1738, 318 million yards of silk thread were spun daily with one water-wheel.

These are happier times for inventors: keen competition among manufacturers does not let a good invention lie idle now. That which was rejected by old machines as waste is now worked up into useful fabrics by new ones. From all parts of the world new products come—jute from India, flax from New Zealand, and many others which demand new adaptations of old machines, or new and untried mechanical arrangements to utilize them. Time would fail me if I were to attempt to enumerate one tithe of these rare combinations of mechanical skill; and, indeed, no one will ever appreciate the labour and supreme mental effort required for their construction who has not himself seen them and their wondrous achievements.

Steamboats, the electric telegraph, and railways are more within the cognizance of the world at large; and the progress that has been made in them in little more than one generation is better known and appreciated.

It is not more than forty years since one of our scientific men, and an able one too, declared at a meeting of this Association that no steamboat would ever cross the Atlantic, founding his statement on the impracticability, in his view, of a steamboat carrying sufficient coal (profitably, I presume) for the voyage. Yet soon after this statement was made, the 'Sirius' steamed to New York in seventeen days*, and was soon followed from Bristol by the 'Great Western,' which made the homeward passage in thirteen days and a half; and with these voyages the era of steamboats may be said to have begun. Like most important inventions, that of the steamboat was a long time in assuming a form capable of being profitably utilized; and even when it had assumed such a form, the objections of commercial and scientific men had still to be overcome.

* First steamer crossed the Atlantic by steam alone in 1838.

Among the many names connected with the early progress in the construction of steamboats, perhaps none is more worthy of remembrance than that of Patrick Miller, who, with the assistance of Symington, an engineer, and Taylor, who was his children's tutor, constructed a small steamboat. Shortly afterwards Lord Dundas, who saw the value of the application of steam for the propulsion of boats, had the first really practical steamboat constructed with a view to using it on the Forth and Clyde Canal. The proprietors, however, objected, and the boat lay idle. Again another attempt to make practical use of the steamboat failed through the death of the Duke of Bridgewater, who, with his characteristic foresight, had seen the value of steam as a motive power for boats, and had determined to introduce steamboats on the canal which bears his name.

The increase in the number of steamboats since the time when the 'Sirius' first crossed the Atlantic has been very great. Whereas in 1814 the United Kingdom only possessed two steam-vessels, of together 456 tons burden, in 1872 there were on the register of the United Kingdom 3,662 steam-vessels, of which the registered tonnage amounted to over a million and a half of tons*, or to nearly half the whole steam tonnage of the world, which did not at that time greatly exceed three million tons.

As the number of steamboats has largely increased, so also gradually has their size increased until it culminated, in the hands of Brunel, in the 'Great Eastern.'

A triumph of engineering skill in ship-building, the 'Great Eastern' has not been commercially so successful. In this, as in many other engineering problems, the question is not how large a thing can be made, but how large, having regard to other circumstances, it is proper at the time to make it.

If, as regards the dimensions of steamboats, we have at present somewhat overstepped the limits in the 'Great Eastern,' much still remains to be done in perfecting the form of vessels, whether propelled by steam or driven by the force of the wind. A distinguished member of this Association, Mr. Froude, has now for some years devoted himself to investigations carried on with the view to ascertain the form of vessel which will offer the least resistance to the water through which it must pass. So many of us in these days are called upon to make journeys by sea as well as by land, that we can well appreciate the value of Mr. Froude's labours, so far as they tend to curtail the time which we must spend on our ocean journeys; and we should all feel grateful to him if from another branch of his investigations, which relates to the rolling of ships, it should result that the movement in passenger vessels could be reduced. A gallant attempt in this direction has lately been made by Mr. Bessemer; whether a successful one yet remains to be proved. In any event, he and those who have acted with him deserve our praise for an experiment which must add to our knowledge.

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* Board of Trade Return, 15th July, 1874, Table 8.

It is a question of vital importance to the steamboat that the consumption of fuel should be reduced to the smallest possible amount, inasmuch as each ton of fuel excludes a ton of cargo.

As improvements in the form of the hull are effected, less power (that is, less fuel) will be required to propel the vessel through the water for a given distance. Great as have been the improvements effected in marine engines to this end, much still remains to be done. Wolf's compound engine, so long overlooked, is, with some improvements, being at last applied. Whereas the consumption of fuel in such vessels as the 'Himalaya' used to be from 5 to 6 lbs. of fuel per effective horse-power, it has been reduced, by working steam more expansively in vessels of a later date, to 2 lbs. Yet, comparing this with the total amount of energy of 2 lbs. of coal, it will be found that not a tenth part of the power is obtained which that amount of coal would theoretically call into action*.

We live in an age when great discoveries are made, and when they are speedily taken advantage of if likely to be of service to mankind.

In former times, man's inventions were frequently in advance of the age, and they were laid aside to await a happier era. There were in those earlier days too few persons who cared to, or who could, avail themselves of the proffered boon, and there was no sufficient accumulation of wealth to justify its being appropriated to schemes which are always in their early stage more or less speculative.

There is no more remarkable instance of the rapid utilization of what was in the first instance regarded by most men as a mere scientific idea, than the adoption and extension of the electric telegraph.

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* Theoretical energy of 1 lb. of coal:—

The proportions of heat expended in generating saturated steam at 212° Fahr., and at 14·7 lbs. pressure per square inch, from water at 212° are:

	Units of heat.	Mechanical equivalent in foot lbs.
I. In the formation of steam	892·8	689,242
II. In resisting the incumbent pressure of 14·7 lbs. per square inch	72·3	55,815
	965·1	745,057

One pound of Welsh coal will theoretically evaporate 15 lbs. of water at 212° to steam at 212°. Therefore the full theoretical value of the combustion of 2 lbs. of Welsh coal is

$$2 \times 15 \times 745{,}057 \text{ foot pounds,}$$

or

$$\frac{2 \times 15 \times 745{,}057}{60 \times 33{,}000} \text{ horse-power, if consumed in 1 hour,}$$

$$= 11{\cdot}2 \text{ horse-power.}$$

As the consumption of coal per effective horse-power in a marine engine is 2 lbs., the power obtained is to the whole theoretical power as 1 is to 11.

Those who read Odier's letter written in 1773, in which he made known his idea of a telegraph which would "enable the inhabitants of Europe to converse with the Emperor of Mogul," little thought that in less than a century a conversation between persons at points so distant would be possible. Still less did those who saw in the following year messages sent from one room to another by Lesage, in the presence of Friedrich of Prussia, realize that they had before them the germ of one of the most extraordinary inventions among the many that will render this century famous.

I should weary you were I to follow the slow steps by which the electric telegraph of to-day was brought to its present state of efficiency. In the present century few years have passed without new workers appearing in the field; some whose object was to utilize the new-found power for the benefit of mankind, others (and their work was not the least important in the end) whose object was to investigate magnetism and electrical phenomena as presenting scientific problems still unsolved. Galvani, Volta, Oersted, Arago, Sturgeon, and Faraday, by their labours, helped to make known the elements which rendered it possible to construct the electric telegraph. With the battery, the electric coil, and the electro-magnet, the elements were complete, and it only remained for Sir Charles Wheatstone and others to combine them in a useful and practically valuable form. The inventions of Alexander, Steinheil, and those of similar nature to that of Sir Charles Wheatstone, were made known at a later date in the same year, which will ever be memorable in the annals of telegraphy*.

The first useful telegraph was constructed upon the Blackwall Railway in 1838, Messrs. Cooke & Wheatstone's instruments being employed. From that time the progress of the electric telegraph has been so rapid, that at the present time, including land lines and submarine cables, there are in use in different parts of the world not less than 400,000 miles of telegraph.

Among the numerous inventions of late years, the automatic telegraphs of Mr. Alexander Bain, of Dr. Werner Siemens, and of Sir Charles Wheatstone are especially worthy of notice. Mr. Bain's machine is chiefly used in the United States, that of Dr. Werner Siemens in Germany. In this country the machine invented by Sir Charles Wheatstone, to whom telegraphy owes so much, is chiefly employed. By his machine, after the message has been punched out in a paper ribbon by one machine, on a system analogous to the dot and dash of Morse, the sequence of the currents requisite to transmit the message along the wire is automatically determined in a second machine by this perforated ribbon. This second operation is analogous to that by which in Jacquard's loom the motions of the threads requisite to produce the pattern is determined by perforated cards. By Wheatstone's machine errors inseparable from manual labour are avoided; and, what is of even more importance in a commercial point of view, the time during which the wire is occupied in the transmission of a message is considerably diminished.

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* Dates of patents: Wheatstone, March 1, 1837; Alexander, April 22, 1837; Steinheil, July 1, 1837; Morse, October 1837.

By the application of these automatic systems to telegraphy, the speed of transmission has been wonderfully accelerated, being equal to 200 words a minute—that is, faster than a shorthand writer can transcribe; and, in fact, words can now be passed along the wires of land lines with a velocity greater than can be dealt with by the human agency at either end.

Owing partly to the retarding effects of induction and other causes, the speed of transmission by long submarine cables is much smaller. With the cable of 1858 only 2½ words per minute were got through. The average with the Atlantic cable, Dr. C. W. Siemens informs me, is now 17 words; but 24 words per minute can be read.

One of the most striking phenomena in telegraphy is that known as the duplex system, which enables messages to be sent from each end of the same wire at the same time. This simultaneous transmission from both ends of a wire was proposed in the early days of telegraphy, but, owing to imperfect insulation, was not then found to be practicable; but since then telegraphic wires have been better insulated, and the system is now becoming of great utility, as it nearly doubles the capacity for work of every wire.

And yet within how short a period of time has all the wonderful progress in telegraphy been achieved! How incredulous the world a few years ago would have been if then told of the marvels which in so short a space of time were to be accomplished by its agency!

It is not long ago (1823) that Mr. (afterwards Sir Francis) Ronald, one of the early pioneers in this field of science, published a description of an electric telegraph. He communicated his views to Lord Melville, and that nobleman was obliging enough to reply that the subject should be inquired into; but before the nature of Sir Francis Ronald's suggestions could be known, except to a few, that gentleman received a reply from Mr. Barrow "that telegraphs of any kind were then wholly unnecessary, and that no other than the one then in use would be adopted," the one then in use being the old semaphore, which, crowning the tops of hills between London and Portsmouth, seemed perfection to the Admiralty of that day.

I am acquainted with some who, when the first Transatlantic cable was proposed, contributed towards that undertaking with the consciousness that it was only an experiment, and that subscribing to it was much the same thing as throwing their money into the sea. Much of this cable was lost in the first attempt to lay it; but its promoters, nothing daunted, made 900 miles more cable, and finally laid it successfully in the following year, 1858.

The telegraphic system of the world comprises almost a complete girdle round the earth; and it is probable that the missing link will be supplied by a cable between San Francisco in California and Yokohama in Japan.

How resolute and courageous those who engaged in submarine telegraphy have been will appear from the fact that, though we have now 50,000 miles of cable in use, to get at this result nearly 70,000 miles were constructed and laid. This large percentage of failure, in the opinion of Dr. C. W. Siemens (to whom I am much indebted for information on this subject), was partly due to the late introduction of testing a cable under water before it is laid, and to the use of too light iron sheathing.

Of immense importance in connexion with the subsequent extension of submarine cables have been the discoveries of Ohm and Sir William Thomson, and the knowledge obtained that the resistance of wire in homogeneous metal is directly proportional to the length, so that the place of a fault in a cable of many thousand miles in length can be ascertained with so much precision as to enable you to go at once to repair it, although the damaged cable may lie in some thousands of fathoms of water.

Of railways the progress has been enormous; but I do not know that in a scientific point of view a railway is so marvellous in its character as the electric telegraph. The results, however, of the construction and use of railways are more extensive and widespread, and their utility and convenience brought home to a larger portion of mankind. It has come to pass, therefore, that the name of George Stephenson has been placed second only to that of James Watt; and as men are and will be estimated by the advantages which their labours confer on mankind, he will remain in that niche, unless indeed some greater luminary should arise to outshine him. The merit of George Stephenson consisted, among other things, in this, that he saw more clearly than any other engineer of his time the sort of thing that the world wanted; and that he persevered, in despite of learned objectors, with the firm conviction that he was right and they were wrong, and that there was within himself the power to demonstrate the accuracy of his convictions.

Railways are a subject on which I may (I hope without tiring you) speak somewhat more at length. The British Association is peripatetic, and without railways its meetings, if held at all, would, I fear, be greatly reduced in numbers. Moreover, you have all an interest in them: you all demand to be carried safely, and you insist on being carried fast. Besides, everybody understands, or thinks he understands, a railway; and therefore I shall be speaking on a subject common to all of us, and shall possibly only put before you ideas which others as well as myself have already entertained.

We who live in these days of roads and railways, and can move with a fair degree of comfort, speed, and safety, almost where we will, can scarcely realize the state of England two centuries ago, when the years of opposition which preceded the era of coaches began; when, as in 1662, there were but six stages in all England, and John Crossdell, of the Charterhouse, thought there were six too many; when Sir Henry Herbert, a member of the House of Commons, could say, "If a man were to propose to carry us regularly to

Edinburgh in coaches in seven days, and bring us back in seven more, should we not vote him to Bedlam?"

In spite of short-sighted opposition, coaches made their way; but it was not until a century later, in 1784 (and then, I believe, it was in this city of Bristol), that coaches were first established for the conveyance of mails. Those here who have experienced, as I have, what the discomforts were of long journeys inside the old coaches, will agree with me that they were very great; and I believe, if returns could be obtained of the accidents which happened to coaches, it would be found that many more people were injured and killed in proportion to the number that travelled by that mode, than by the railways of to-day.

No sooner had our ancestors settled down with what comfort was possible in their coaches, well satisfied that twelve miles an hour was the maximum speed to be obtained, or was desirable, than they were told that steam conveyance on iron railways would supersede their "present pitiful" methods of conveyance. Such was the opinion of Thomas Gray, the first promoter of railways, who published his work on a general iron railway in 1819. Gray was looked on as little better than a madman. "When Gray first proposed his great scheme to the public," said Chevalier Wilson, in a letter to Sir Robert Peel in 1845, "people were disposed to treat it as an effusion of insanity." I shall not enter on a history of the struggles which preceded the opening of the first railway. They were brought to a successful issue by the determination of a few able and far-seeing men. The names of Thomas Gray and Joseph Sandars, of William James and Edward Pease, should always be remembered in connexion with the early history of railways, for it was they who first made the nation familiar with the idea. There is no fear that the name of Stephenson will be forgotten, whose practical genius made the realization of the idea possible.

The Stockton and Darlington Railway was opened in 1825, the Liverpool and Manchester Railway in 1830; and in the short time which has since elapsed, railways have been extended to every quarter of the globe. No nation possessing wealth and population can afford to be without them; and though at present in different countries there is in the aggregate about 160,000 miles of railway, it is certain that in the course of a very few years this quantity, large as it is, will be very greatly exceeded.

Railways add enormously to the national wealth. More than twenty-five years ago it was proved to the satisfaction of a committee of the House of Commons, from facts and figures which I then adduced, that the Lancashire and Yorkshire Railway, of which I was the engineer, and which then formed the principal railway connexion between the populous towns of Lancashire and Yorkshire, effected a saving to the public using the railway of more than the whole amount of the dividend which was received by the proprietors. These calculations were based solely on the amount of traffic carried by the railway, and on the difference between the railway rate of charge and the charges by the modes of conveyance anterior to railways. No credit whatever was taken for the saving of time, though in England preeminently time is money.

Considering that railway charges on many items have been considerably reduced since that day, it may be safely assumed that the railways in the British Islands now produce, or rather save the nation, a much larger sum annually than the gross amount of all the dividends payable to the proprietors, without at all taking into account the benefit arising from the saving in time. The benefits under that head defy calculation, and cannot, with any accuracy, be put into money; but it would not be at all over-estimating this question to say that in time and money the nation gains at least what is equivalent to 10 per cent. on all the capital expended on railways. I do not urge this on the part of railway proprietors, for they did not embark in these undertakings with a view to the national gain, but for the expected profit to themselves. Yet it is as well it should be noted; for railway proprietors appear sometimes by some people to be regarded in the light of public enemies.

It follows from these facts that whenever a railway can be made at a cost to yield the ordinary interest of money, it is in the national interest that it should be made. Further, that though its cost might be such as to leave a smaller dividend than that to its proprietors, the loss of wealth to so small a section of the community will be more than supplemented by the national gain, and therefore there may be cases where a government may wisely contribute in some form to undertakings which, without such aid, would fail to obtain the necessary support.

And so some countries, Russia for instance, to which improved means of transport are of vital importance, have wisely, in my opinion, caused lines to be made which, having regard to their own expenditure and receipts, would be unprofitable works, but in a national point of view are or speedily will be highly advantageous.

The empire of Brazil also, which I have lately visited, is arriving at the conclusion, which I think not an unwise one, that the State can afford and will be benefited in the end by guaranteeing 7 per cent. upon any railway that can of itself be shown to produce a net income of 4 per cent., on the assumption that the nation will be benefited at least to the extent of the difference.

A question more important probably in the eyes of many—safety of railway travelling—may not be inappropriate. At all events, it is well that the elements on which it depends should be clearly understood. It will be thought that longer experience in the management of railways should go to ensure greater safety; but there are other elements of the question which go to counteract this in some degree.

The safety of railway travelling depends on the perfection of the machine in all its parts, including the whole railway, with its movable plant, in that term; it depends also on the nature and quantity of traffic, and, lastly, on human care and attention.

With regard to what is human, it may be said that so many of these accidents as arise from the fallibility of men will never be eliminated until the race be improved.

The liability to accident will also increase with the speed, and might be reduced by slackening that speed. It increases with the extent and variety of the traffic on the same line. The public, I fear, will rather run the risk than consent to be carried at a slower rate. The increase in extent and variety of traffic is not likely to receive any diminution; on the contrary, it is certain to augment.

I should be sorry to say that human care may not do something; and I am not among those who object to appeals through the press, and otherwise, to railway companies, though sometimes perhaps they may appear in an unreasonable form. I see no harm in men being urged in every way to do their utmost in a matter so vital to many.

A question may arise whether, if the railways were in the hands of the Government, they could not be worked with greater safety. Government would not pay their officers better, or perhaps so well as the companies do, and it is doubtful whether they would succeed in attracting to the service abler men. They might do the work with a smaller number of chief officers; for much of the time of the companies' managers is occupied in internecine disputes. They might handle the traffic more despotically, diminishing the number of trains, or the accommodation afforded by them, or in other ways, to insure more safety; but would the public bear any curtailment of convenience?

One thing they could, and perhaps would do. In cases where the traffic is varied, and could more safely be conducted with the aid of relief lines, which hold out no sufficient inducement to the companies to make, the Government, being content with a lower rate of interest, might undertake to make them, though then comes the question whether, when the whole of this vast machine came to depend for supplies on annual votes of Parliament, money would be forthcoming in greater abundance than it is under the present system.

But the consideration of this subject involves other and more difficult questions.

Where are the labours of Government to stop? The cares of State which cannot be avoided are already heavy, and will grow heavier every year. Dockyard establishments are trifling to what the railway establishments, which already employ 250,000 men, would be. The assumption of all the railways would bring Government into conflict with every passenger, every trader, every merchant, and every manufacturer. With the railway companies there would be no difficulty; they would sell their undertakings to any one provided the price was ample.

Looking at the vast growth of railway traffic, one measure occurs to me as conducive to the safety of railway passengers, and likely to be demanded some day: it is to construct between important places railways which should carry passengers only or coals only, or be set apart for some special separation of traffic; though there will be some difficulty in accomplishing this. Landowners, through whose property such lines would pass, would probably wish to use such lines for general purposes. Nevertheless it may have to be tried some day.

It would be instructive, were it practicable, to compare the relative proportion of accidents by railway and by the old stage-coaches; but no records that I am aware of exist of the latter that would enable such a comparison to be made. It is practicable to make some sort of comparison between the accidents in the earlier days of our own railways and the accidents occurring at a later date.

The Board of Trade have unfortunately abandoned the custom, which they adopted from 1852 to 1859, of returning the passenger mileage, which is given in the German returns, and is the proper basis upon which to found the proportion of accidents, and not on the number of passengers without any regard to distance travelled, which has altered very much, the average journey per passenger being nearly half in 1873 what it was in 1846.

It would be erroneous to compare the proportions of accidents to passengers carried in various years, even if the correct number of passengers travelling were given. But a figure is always omitted from the Board of Trade return, which makes the proportion of accidents to passengers appear larger than it is; this is the number of journeys performed by season-ticket holders. Some estimate could be made of the journeys of season-ticket holders by dividing the receipts by an estimated average fare, or the companies could make an approximate estimate, and the passenger mileage could be readily obtained by the railway companies from the tickets. These additions would greatly add to the value of the railway returns as statistical documents, and render the deductions made from them correct.

Though it has been a work of labour, I have endeavoured to supply these deficiencies, and I believe the results arrived at may be taken as fairly accurate*.

From the figures so arrived at, it appears the passenger mileage has doubled between 1861 and 1873; and at the rate of increase between 1870 and 1873 it would become double what it was in 1873 in twelve years from that time, namely in 1885.

The number of passengers has doubled between 1864 and 1873, and at the rate of increase between 1870 and 1873 it would become double what it was in 1873 in eleven years and a half, or in 1885.

It must, however, be remembered that the rate of increase since 1870, though very regular for 1871, 1872, and 1873, is greater than in previous years, being probably due to the rise of wages and the great development of third-class traffic, and it would not be safe to assume this rate of increase will continue.

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* See Table in Appendix.

Supposing no improvement had been effected in the working of railway traffic by the interlocking of points, the block system, &c., the increase of accidents should have borne some proportion to the passenger mileage, multiplied by the proportion between the train mileage and the length of line open, as the number of trains passing over the same line of rails would tend to multiply accidents in an increasing proportion, especially where the trains run at different speeds.

The number of accidents varies considerably from year to year; but taking two averages of ten years each, it appears that the proportion of deaths of passengers from causes beyond their control to passenger miles travelled in the ten years ending December 31, 1873, was only two thirds of the same proportion in the ten years ending December 31, 1861; the proportion of all accidents to passengers from causes beyond their own control was one ninth more in the last ten years than in the earlier, whereas the frequency of trains had increased on the average one fourth.

The limit, however, of considerable improvements in signalling, increased brake-power, &c. may be reached before long; and if so, the increase of accidents will then depend on the increase of traffic, together with the increased frequency of trains.

The large growth of railway traffic, which we may assume will double in twenty years, will evidently greatly tax the resources of the railway companies; and unless the present companies increase the number of the lines of way, as some have commenced to do, or new railways are made, the system of expeditious and safe railway travelling will be imperilled. Up to the present time, however, the improvements in regulating the traffic appear to have kept pace with the increase of traffic and of speed, as the slight increase in the proportion of railway accidents to passenger miles is probably chiefly due to a larger number of trifling bruises being reported now than formerly.

I believe it was a former President of the Board of Trade who said to an alarmed deputation, who waited upon him on the subject of railway travelling, that he thought he was safer in a railway carriage than anywhere else.

If he gave any such opinion, he was not far wrong, as is sufficiently evident when it can be said that there is only one passenger injured in every four million miles travelled, or that, on an average, a person may travel 100,000 miles each year for forty years, and the chances be slightly in his favour of his not receiving the slightest injury.

A pressing subject of the present time is the economy of fuel. Members of the British Association have not neglected this momentous question.

At the meeting held at Newcastle-on-Tyne in 1863, Sir William Armstrong sounded an alarm as to the proximate exhaustion of our coal-fields.

Mr. Bramwell, when presiding over the Mechanical Section at Brighton, drew attention to the waste of fuel.

Dr. Siemens, in an able lecture he delivered by request of the Association to the operative classes at the meeting at Bradford, pointed out the waste of fuel in special branches of the iron trade, to which he has devoted so much attention.

He showed on that occasion that, in the ordinary reheating furnace, the coal consumed did not produce the twentieth part of its theoretical effect, and in melting steel in pots in the ordinary way not more than one-seventieth part, in melting one ton of steel in pots about 2½ tons of coke being consumed. Dr. Siemens further stated that, in his regenerative gas-furnace, one ton of steel was melted with 12 cwt. of small coal.

Mr. Lowthian Bell, who combines chemical knowledge with the practical experience of an ironmaster, in his Presidential address to the Members of the Iron and Steel Institute in 1873, stated that, with the perfect mode of withdrawing and utilizing the gases and the improvement in the furnaces adopted in the Cleveland district, the present make of pig iron in Cleveland is produced with 3½ million tons of coal less than would have been needed fifteen years ago, this being equivalent to a saving of 45 per cent. of the quantity formerly used. He shows by figures, with which he has favoured me, that the calorific power of the waste gases from the furnaces is sufficient for raising all the steam and heating all the air the furnaces require.

It has already been stated that by working steam more expansively, either in double or single engines, the consumption of fuel in improved modern engines compared with the older forms may be reduced to one third.

All these reductions still fall far short of the theoretical effect of fuel, which may be never reached. Mr. Lowthian Bell's figures go to show that in the interior of the blast-furnace, as improved in Cleveland, there is not much more to be done in reducing the consumption of fuel; but much has already been done; and could the reductions now attainable and all the information already acquired be universally applied, the saving in fuel would be enormous.

How many open blast-furnaces still belch forth flame and gas and smoke as uselessly, and with nearly as much mischief to the surrounding neighbourhood, as the fires of Etna or Vesuvius!

How many of the older and more extravagant forms of steam-engine still exist!

What is to be done with the intractable householder, with the domestic hearth, where, without going to German stoves, but by using Galton's grates and other improvements, every thing necessary both for comfort and convenience could be as well attained with a much smaller consumption of coal?

If I have pointed out that we do not avail ourselves of more than a fractional part of the useful effects of fuel, it is not that I expect we shall all at once mend our ways in this respect.

Many cases of waste arise from the existence of old and obsolete machines, of bad forms of furnaces, of wasteful grates, existing in most dwelling-houses; and these are not to be remedied at once; for not every one can afford, however desirable it might be, to cast away the old and adopt the new.

In looking uneasily to the future supply and cost of fuel, it is, however, something to know what may be done even with the application of our present knowledge; and could we apply it universally to-day, all that is necessary for trade and comfort could probably be as well provided for by one half the present consumption of fuel; and it behoves those who are beginning to build new mills, new furnaces, new steamboats, or new houses to act as though the price of coal which obtained two years ago had been the normal and not the abnormal price.

There was in early years a battle of the gauges, and there is now a contest about guns; but your time will not permit me to say much on their manufacture.

Here, again, the progress made in a few years has been enormous; and in contributing to it, two men, Sir William Armstrong and Sir Joseph Whitworth, both civil engineers, in this country at all events, deservedly stand foremost. The iron coil construction of Sir William Armstrong has already produced remarkable and satisfactory results; in discussing further possible improvements, the question is embarrassed by attempting to draw sharp lines between what is called steel and iron.

There is nothing that I can see to limit the size of guns, except the tenacity and endurance of the metal, whatever we may choose to call it, of which they are to be made.

Sir Joseph Whitworth, who has already done more than any other man in his department to secure good workmanship, and whose ideal of perfection is ever expanding, has long been seeking, and not without success, by enormous compression, to increase those qualities in what he calls homogeneous metal. Make the metal good enough, and call it iron if you will, and the size of a gun may be any thing: the mere construction and handling of a gun of 100 tons, or of greater weight, with suitable mechanical appliances, presents no difficulty.

Relying on the qualities of his compressed metal, Sir Joseph is now seeking by a singular experiment to limit the travel of the recoil, as far as practicable, to the elasticity of the metal. By attaching the muzzle of the gun to an outer casing, through which the force of the recoil is carried back to the trunnions, he proposes to avail himself of this elasticity to the extent of once and a half the length of the gun; whether its elasticity alone in so short a space will suffice without other aid is, perhaps, doubtful; but other aid may be applied, and the experiment, whether successful or not, will be interesting.

Docks and harbours I have no time to mention; for it is time this long and, I fear, tedious address should close.

"Whence and whither," is an aphorism which leads us away from present and plainer objects to those which are more distant and obscure; whether we look backwards or forwards, our vision is speedily arrested by an impenetrable veil.

On the subjects I have chosen you will probably think I have travelled backwards far enough. I have dealt to some extent with the present.

The retrospect, however, may be useful to show what great works were done in former ages.

Some things have been better done than in those earlier times, but not all.

In what we choose to call the ideal we do not surpass the ancients. Poets and painters and sculptors were as great in former times as now; so, probably, were the mathematicians.

In what depends on the accumulation of experience, we ought to excel our forerunners. Engineering depends largely on experience; nevertheless, in future times, whenever difficulties shall arise or works have to be accomplished for which there is no precedent, he who has to perform the duty may step forth from any of the walks of life, as engineers have not unfrequently hitherto done.

The marvellous progress of the last two generations should make every one cautious of predicting the future. Of engineering works, however, it may be said that their practicability or impracticability is often determined by other elements than the inherent difficulty in the works themselves. Greater works than any yet achieved remain to be accomplished—not, perhaps, yet awhile. Society may not yet require them; the world could not at present afford to pay for them.

The progress of engineering works, if we consider it, and the expenditure upon them, has already in our time been prodigious. One hundred and sixty thousand miles of railway alone, put into figures at £20,000 a mile, amounts to 3200 million pounds sterling; add 400,000 miles of telegraph at £100 a mile, and 100 millions more for sea canals, docks, harbours, water and sanitary works constructed in the same period, and we get the enormous sum of 3340 millions sterling expended in one generation and a half on what may undoubtedly be called useful works.

The wealth of nations may be impaired by expenditure on luxuries and war; it cannot be diminished by expenditure on works like these.

As to the future, we know we cannot create a force; we can, and no doubt shall, greatly improve the application of those with which we are acquainted. What are called inventions can do no more than this; yet how much every day is being done by new machines and instruments.

The telescope extended our vision to distant worlds. The spectroscope has far outstripped that instrument, by extending our powers of analysis to regions as remote.

Postal deliveries were and are great and able organizations; but what are they to the telegraph?

Need we try to extend our vision into futurity further? Our present knowledge, compared to what is unknown even in physics, is infinitesimal. We may never discover a new force—yet, who can tell?

APPENDIX.

RAILWAY ACCIDENTS.—*Great Britain and Ireland.*

Year.	Proportion of train mileage for year to total length of single line of way, excluding sidings.	Number of accidents to passenger trains.	Average journey of passengers of all classes, exclusive of periodical ticket-holders.	Number of accidents to passengers from causes beyond their control.			Number of miles travelled by passengers of all classes, including periodical ticket-holders.	Proportion of passengers killed from causes beyond their control to passenger miles travelled.	Proportion of passengers injured or killed from causes beyond their control to passenger miles travelled.	Proportion of passengers killed from causes beyond their control to passenger journeys.	Proportion of passengers injured or killed from causes beyond their control to passenger journeys.
				Killed.	Injured.	Total.					
I.	II.	III.	IV.	V.	VI	VII.	VIII.	IX	X.	XI.	XII.
	(*a*)	No.	miles.	No.	No	No.	(*b*) miles.	(*c*) miles.	(*d*) miles.	(*e*) No.	(*f*) No.
1846.	......	51	18·80	5	146	151	894,573,000	1 in 178,915,000	1 in 5,924,000	1 in 9,514,000	1 in 315,000
1849.	......	33	18·21	5	84	89	1.162,806,000	1 in 232,561,000	1 in 13,065,000	1 in 12,768,000	1 in 717,000
1852.	......	60	16·19	10	372	382	1,473,255,000	1 in 147,326,000	1 in 3,857,000	1 in 8,910,000	1 in 241,000
1855.	5134	75	15·34	10	311	321	1,864,175.000	1 in 186,418,000	1 in 5,807,000	1 in 12,316,000	1 in 384,000
1858.	5418	48	14·54	25	419	444	2,084,353,000	1 in 83,374,000	1 in 4,694,000	1 in 5,809,000	1 in 327,000
1861.	5921	55	14·21	46	780	826	2,547,653,000	1 in 55,384,000	1 in 3,084,000	1 in 3,947,000	1 in 220,000
1864.	6395	75	12·47	14	697	711	2,966,592,000	1 in 211,899,000	1 in 4,172,000	1 in 17,141,000	1 in 338,000
1867.	6724	94	11·56	19	689	708	3,478,262,000	1 in 183,066,000	1 in 4,913,000	1 in 15,947,000	1 in 428,000
1870.	7253	123	10·74	65	1084	1149	3,801,734,000	1 in 58,488,000	1 in 3,309,000	1 in 5,465,000	1 in 309,000
1873.	7894	....	10·53	38	1504	1542	5,060,329,000	1 in 133,167,000	1 in 3,282,000	1 in 12,683,000	1 in 313,000
Average	1852–61	(inclusive)	.....	20	425	445	2,018,485,000	1 in 100,924,000	1 in 4,536,000	1 in 6,850,000	1 in 308,000
Average	1864–73	(inclusive)	......	26	920	946	3,826,729,000	1 in 147,182,000	1 in 4,045,000	1 in 13,165,000	1 in 362,000

(*a*) The figures in this column are obtained by dividing the total train mileage by the aggregate length of single line of way, excluding sidings, and not by the actual length of the railway.

(*b*) The passenger mileage has been calculated, as it is not given in the Board of Trade returns, except partially between 1852 and 1859 (inclusive), and since 1859 no return under this head has been made.

(*c*) The figures in column No. IX. are obtained by dividing those in column VIII. by those in column V.

(*d*) The figures in column X. are obtained by dividing those in column VIII. by those in column VII.

(*e*) The figures in column XI. are obtained by dividing the total number of passengers carried in each year (including a calculated number of journeys made by season-ticket holders) by the figures in column V.

(*f*) The figures in column XII. are obtained by dividing the total number of passengers carried in each year by the figures in column VII.

N.B.—The passenger mileage includes the miles estimated to have been travelled by season-ticket holders. This estimate was obtained by calculating an average fare per mile for each class of passenger, and dividing the receipts from the season-ticket holders by the average fare

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REPORTS

ON

THE STATE OF SCIENCE.

Eleventh Report of the Committee for Exploring Kent's Cavern, Devonshire—the Committee consisting of Sir JOHN LUBBOCK, *Bart., F.R.S.,* JOHN EVANS, *F.R.S.,* EDWARD VIVIAN, *M.A.,* GEORGE BUSK, *F.R.S.,* WILLIAM BOYD DAWKINS, *F.R.S.,* WILLIAM AYSHFORD SANFORD, *F.G.S.,* JOHN EDWARD LEE, *F.G.S., and* WILLIAM PENGELLY, *F.R.S.* (*Reporter*).

THE Committee have again the melancholy duty of reporting that death has deprived them of one of their members. As long ago as 1859, as soon as he became aware of the importance of the discoveries made in the Windmill-Hill Cavern at Brixham, Sir Charles Lyell expressed a strong desire that Kent's Cavern should also be systematically and thoroughly explored; and it was with his full concurrence that the proposal to do so was laid before the Committee of the Geological Section of the British Association at Bath in 1864, the day after he delivered his Presidential Address; whilst his ardent advocacy, together with that of the late Professor Phillips, secured its ready acceptance by the Committee of Recommendations and the General Committee. At the first meeting of the Cavern Committee, appointed in the year just mentioned, he was unanimously elected Chairman, and he continued to occupy that post until his lamented decease on 27th February, 1875. Though the state of his health prevented him from taking any active part in the exploration, his interest in the work never abated; he always carefully studied the Monthly Reports of Progress sent him by the Superintendents, and he made careful arrangements for their preservation.

The Tenth Report, read to the Geological Section of the Association at the Belfast Meeting, and printed in the annual volume for last year, brought up the work to the end of July 1874. The exploration has been carried on without interruption from that date to the present time, the mode of excavation adopted at the beginning has been uniformly followed, the Superintendents have visited the Cavern daily, the progress of the work has been carefully recorded in the Cavern diary, the workmen have, as heretofore, given complete satisfaction, and Monthly Reports have been regularly sent to Sir Charles Lyell until his decease, and subsequently to Mr. John Evans.

The Committee have the satisfaction of stating that they still retain the services of George Smerdon, foreman of the work, who has been engaged on it from the beginning. As John Clinnick, the second workman, believing the employment prejudicial to his health, has sought more congenial labour, they have engaged Nicholas Luscombe in his stead, and hope that he may prove an equally satisfactory workman.

The Cavern continues to be much visited by persons desirous of studying on the spot its characters and phenomena; and during the last twelve months the Superintendents have had the pleasure of taking the following gentlemen through those branches which have been explored, and of explaining to them the mode of operation:—Sir C. Wheatstone, General D. Lysons, Colonel Brine, Major J. Virtue (Madras), the Revs. Dr. Stebbing, J. L. Ball, W. E. Buckley, G. Henslow, J. Parker, T. R. R. Stebbing, T. Talbot, J. H. Tooke, and R. H. J. Turrell, Dr. T. Oldham (Calcutta), Dr. E. B. Tylor, and Messrs. E. W. Alexander (New Zealand), W. F. Alexander, A. R. Baker, J. R. Baker, H. S. Ball, W. Beer, C. A. Bleckly, H. F. Bleckly, Gellings Blow, A. Brine, N. Brown, M. de Bunsen, W. Carruthers, Moncure D. Conway, J. D. Crossfield, P. L. Davidson, W. J. Dobie, F. Elder, E. C. Elliott, W. Francis, G. S. Gibson, J. Giles, H. Gurney, T. Gurney, T. Harrison, T. N. Hart-Smith, E. S. Hastings, F. J. Hext, C. Holdsworth, J. Holdsworth, J. A. Holdsworth, J. H. Holdsworth, J. S. Holdsworth, R. Holdsworth, A. R. Hunt, T. Hunton, H. J. J. Lavis, J. Norman Lockyer, D. C. W. Lysons, J. I. Mackenzie, D. Pidgeon, A. D. Powell, H. Reuter, A. Richardson, A. F. Robinson, H. Segar, J. Sollas, E. B. Stott, J. S. Stott, F. R. Thomson, J. R. Terry, H. Tozer, J. H. Tuke, S. Tuke, W. S. Tuke, W. A. E. Ussher, C. Staniland Wake, E. G. Wake, J. C. Wheat, J. N. White, B. H. Williams, F. Williams, F. R. Wolfe, B. B. Woodward, H. B. Woodward, and F. L. Woodward.

Numerous visitors have also been conducted by the "Guide," who, though under the control of the Committee, is not permitted to take parties to those branches of the Cavern in which the exploration is in progress or has not been begun.

As in former years, rats have frequently been seen running about in various parts of the Cavern, including those in which the men have been at work, though hundreds of feet from any glimmering of daylight; and they have displayed their usual boldness as well as their skill in carrying off candles. In other branches, almost as far from the entrances, where all researches have ceased for some years, their footprints are to be seen in very great numbers, especially on the silt left, here and there, where the drip is copious in wet weather. It is difficult to understand what draws them thither, unless it be the small amount of tallow which drops from the candles of visitors.

On 29th January, 1875, a "buzzing fly" was heard by one of the Superintendents in "The Cave of Inscriptions," about 300 feet from daylight, and was subsequently seen by the workmen in the same Cave.

Clinnick's Gallery.—The Tenth Report (1874) stated that the Committee had discovered that the "Long Arcade," about 225 feet from its entrance, threw off a narrow branch, which had been named "Clinnick's Gallery" after the workman who first entered it—that its exploration was in progress and had been completed for about 34 feet—that below the least ancient, or the "Granular, Stalagmitic Floor," for a distance of 18 feet from the entrance, a small quantity of "Cave-earth" uniformly presented itself, beneath which lay the "Breccia," occasionally separated from it by remnants of the more ancient, or the "Crystalline, Stalagmitic Floor" *in situ*—but that from the point just named, up to that reached when the Tenth Report was drawn, there was no Cave-earth; so that the two Stalagmites lay the one immediately on the other, with the Breccia (that is, as far as is known), the oldest of the Cavern deposits, beneath the whole.

At the commencement of the exploration of this Gallery, the deposits so very nearly reached the roof as to induce the belief that a very few feet at most was all that the workmen had before them. In short, no one suspected the existence of this branch of the Cavern. As the work advanced, however, the unoccupied interspace between the roof and floor became gradually larger, until on the 6th of August, 1875, John Clinnick, the workman already mentioned, forced himself through, and, after proceeding about 50 feet, as he estimated, entered a large chamber, of which he brought back such a glowing description as to induce one of the Superintendents to follow him, when he found the workman's description by no means too highly coloured. The Chamber, probably one of the largest in the Cavern, is beautifully hung with stalactites, and has numerous stalagmitic "paps," some of them four feet high and of almost cylindrical form, rising from a floor of the same material.

The work in Clinnick's Gallery was very difficult, as the two stalagmites were not only extremely hard and tough, but had an aggregate thickness amounting frequently to fully four feet; and the very contracted height and breadth of the Gallery prevented the men from working to the best advantage.

The state of the Floor was a puzzling study. The older, or lower, or Crystalline-Stalagmite was broken in places near the left wall along a line parallel with it, and the fragments, occasionally considerable sheets, were raised some inches above their original level at their margin most remote from the wall and depressed at that nearest to it, whilst every thing remained intact at and adjacent to the opposite wall of the narrow Gallery. The disturbance occurred obviously before the commencement of the formation of the upper or Granular Stalagmite; for not only was this less ancient floor undisturbed, but the fragmentary and tilted sheets of the older floor just mentioned passed in some instances obliquely through it, rising above its upper surface on one side and projecting below its base on the other. Adjacent to the left wall, at a point where the Floor was unbroken, a pap (which had evidently lost its top) reached the height of 16 inches and was still standing erect. Though varying somewhat in diameter, it may be said to be cylindrical in form, and at the top it measured 10 inches in circumference. Almost in contact with it, but lying horizontally at its base, and completely enveloped in the Granular Stalagmite, was a fragment of, no doubt, the same pap, 10 inches long; whilst on the opposite side of the standing portion was a third fragment, 5 inches long, terminating in a cone, and firmly held to the spot by stalagmitic matter. There can be no doubt that the three pieces are portions of one and the same pap, of which the shorter piece was the conical apex, the unbroken column having been at least 31 inches long. Phenomena such as these are calculated to induce speculations respecting the causes which produced them and the time they represent. In the case just mentioned, we have, first, the deposition of the Breccia, or oldest of the Cavern-deposits, so far as is certainly known; this was followed by the formation of the Crystalline Stalagmite as a continuous sheet of somewhat variable thickness, which sometimes reached fully 3 feet in this Gallery; next came that very slow drip and precipitation of carbonate of lime which alone seems compatible with the formation of paps, and this continued until the pap just described had reached a height exceeding 30 inches and a girth of 10; this was succeeded by some cause of disturbance, which broke the thick floor of Crystalline Stalagmite, depressed, as if by subsidence, the deposit adjacent to one wall, but left every thing intact on the opposite side of the narrow passage, broke the pap into three pieces, leaving the lowest of them still erect, causing the middle segment to fall at its foot on the outside, and that which formed the apex on the inside; finally, this was followed by another sheet-like floor of Stalagmite, of less thickness than the former, granular in texture, and capable of preventing the results of the disturbance from being themselves disturbed. A faint earthquake-tremor would, no doubt, suffice to break some of the long comparatively slender paps; for some of those which have been found detached have been known to resolve themselves into fragments, even at a touch, the planes of division being at right angles to the longest axis, whilst others of even less thickness will stand a considerable blow. Most of those standing intact emit a musical note when gently struck; and the notes are such as to show that the rates of vibration, and hence probably the molecular arrangement, must differ considerably even in masses differing but little in dimensions.

Clinnick's Gallery on being excavated was found to be a somewhat tortuous passage, varying from 4 to 8 feet in width, and from 7 to 10 feet in height *. That it was once a watercourse there can be little or no doubt, as the roof bears the marks of the long-continued action of a running stream. The walls vary considerably—being in some places smooth, in others much fretted or corroded, and in others more or less angular.

The objects of interest found in this branch of the Cavern during the last twelve months have been by no means numerous; nevertheless they are not without interest, as a few of them throw a new light on the palæontology of the Cavern.

Attached to the upper surface of the Granular Stalagmitic Floor, the least ancient of the two deposits of that material, portions of three land-shells (No. 6477) were found, 23rd October, 1874; and on the 31st of the same month about 20 bones of Mammals (No. 6481) were met with, lying together loose on the Floor, beneath a few small fragments of Stalagmite. Their characters are such as to imply a recent introduction into the Cavern.

Incorporated in the Granular Stalagmite itself were a few bones, including a humerus (No. 6475), a tibia and ulna (No. 6476), all nearly entire, and a portion of a large humerus (No. 6491), each of which had been gnawed.

Though no Cave-earth was met with beyond the point already specified, there seems no doubt that to the era of that deposit may be referred a considerable portion of a radius (No. 6484) and of an ulna (No. 6489), both gnawed and found under loose pieces of stalagmite.

The Breccia in this Gallery was not much more productive. The total remains of animals it has yielded since the last Report was presented are 4 teeth of Bear, a few bones and fragments of bone, and 3 teeth of Lion in three portions of, no doubt, one and the same lower jaw. The latter "find" (No. 6482) is of considerable interest, as being the first known instance of

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* All heights mentioned in this Report have been measured from the bottom of the excavations made by the Committee.

remains of any animal besides Bear met with in the Breccia. It was found with three bits of bone on the 2nd November, 1874, in the third foot-level; and vertically beneath it, in the next foot-level, were 1 tooth of Bear, a fragment of bone, and a flint chip (No. 6483). Though the Superintendents had no doubt of the feline character of the teeth, they forwarded one of them (that least surrounded with Breccia) to Mr. George Busk, F.R.S. &c., a member of the Committee, on 30th November, 1874, remarking that they believed it to be the last lower left molar of *Felis spelæa*, and requesting his opinion on it. In his reply, dated "32 Harley Street, December 8, 1874," he remarks:—"There is no doubt that the tooth is the left lower carnassial of *Felis leo*, but it is of very unusual size, being, I should estimate, $\frac{1}{12}$ bigger than the average dimensions of that tooth in the Lion. It is usually longer, but not so thick, in the Tiger than in the Lion; but the thickness of the present one is proportionate to its length, viz. 1·20 × ·65 inch. Another peculiarity, as it seems to me, is the great wear that the tooth has undergone. I fancy existing Lions are not allowed to live long enough to wear their teeth so much. At any rate, the Kent's Hole tooth appears to be more worn than any other I have as yet met with. Can it belong to *Machairodus*?

(Signed) "GEORGE BUSK."

Having succeeded in removing some part of the matrix incrusting the other portions of the jaw, they were also forwarded to Mr. Busk, with the observation that the Superintendents had carefully considered the question before submitting the first tooth, and had come to the conclusion that the jaw was not that of *Machairodus*; for, waiving the fact that none of the teeth were serrated, the fang of the canine still remaining in the jaw was much too large for a lower canine of any known species of *Machairodus*; and it was suggested that it might be worth considering whether the specimen belonged to any of the species of *Felis* found in the Forest-bed of Cromer. Mr. Busk says in his reply, dated August 11, 1875:—"The jaw does not appear to present any thing unusual. It is, however, a good example to show that the Cave-Lion lived to a good old age.

(Signed) "GEORGE BUSK."

Clinnick's Gallery also yielded 7 specimens of flint and chert belonging to the Breccia (Nos. 6466, 6467*a*, 6470, 6474, 6478, 6483, and 6485), of which the first and fourth alone require further notice.

No. 6466 is an irregular tongue-shaped tool, of gamboge-colour externally, about 3 inches long, 1·7 inch in greatest breadth, and ·7 inch in greatest thickness. It has been reduced to an edge all round the circumference except at the but-end, is slightly concave on the inner face, on which the "bulb of percussion" is well developed near the but-end, and very convex on the outer face, whence several flakes and chips have been dislodged. It was broken into three pieces by the workmen in extracting it, and was found, without any other object of interest near it, on 8th August, 1874, in the third foot-level of Breccia, over which the two Stalagmitic Floors, without any Cave-earth between them, had an aggregate thickness of 48 inches.

No. 6474, a flint pebble, pretty well rolled, and 2·1 inches long, was found alone, in the second foot-level of Breccia, on 24th September, 1874.

The comparative paucity of specimens in Clinnick's Gallery induced the Superintendents, on 1st December, 1874, to suspend operations in that direction for at least a time. The labour of seven months had been expended on it, during which the exploration had reached 75 feet from the entrance, where the Great Chamber discovered by John Clinnick may be said to begin.

The following is a list of the objects of interest found in Clinnick's Gallery from first to last:—

Lying on the surface, and apparently recent: 3 shells of *Helix* and about 20 bones of Mammals.

Incorporated in the Granular Stalagmite: a few gnawed bones.

In the Cave-earth: 8 teeth of Hyæna, 2 of Fox, a tolerable number of bones and fragments of bone, 1 large Chert implement (No. 6401), and 1 small flint flake (No. 6426).

In the Breccia: 90 teeth of Bear, 3 of Lion in portions of a left lower jaw (No. 6482), numerous bones and portions of bone, including a large part of a skull, a flint pebble, and 11 specimens of flint and chert implements, flakes, and chips, including the very fine tool No. $\frac{1}{6411}$.

The Cave of Inscriptions.—The chamber in which "The Long Arcade" terminates was called by Mr. MacEnery "The Cave of Inscriptions," on account of the number of names, initials, and dates graved on the Stalagmite in various parts of it. Besides those on the "The Inscribed Boss of Stalagmite," at the entrance of the "Cave," described in the Tenth Report (1874), inscriptions occur on what is known as "The Hedges Boss" and on the walls of the Chamber. There are also numerous names &c. smoked on various parts of the Roof, as there are, indeed, in almost every branch of the Cavern, some of which appear to be of considerable antiquity.

The left wall, about 35 feet from the entrance, is covered with Stalagmitic matter, having usually a rough surface, and to which there does not seem to have been recently any addition. On this surface the following inscriptions have been noticed:—

*1. I. O. 2. NW 3. A E
1609 1792
4. 1769

No. 1 is in large badly cut characters.

No. 2 is in characters about 3 inches high, well cut, bold, and very legible. The letters are, of course, an economical form of NW.

No. 3 is badly cut, and immediately under No. 2.

No. 4 is in small characters.

There are several other inscriptions, but not sufficiently legible to be copied with certainty.

At the south-western corner of the Chamber the following inscriptions occur on the wall:—

1. M. R. 2. G. B. 3. H A G H 4. S. G
64 1731
5. I. B.
6. William Mather 7. I M
Teignmouth FAICT DARM
IOhN MARTY
8. R. B 9. 1653 10. D o w n all.
1661

No. 1 is badly cut.

No. 4 is within a square 5·5 inches in the side and looped at each angle.

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* The numerals prefixed to the inscriptions do not belong to the originals.

Nos. 6 and 10 are in ordinary *written* characters.

No. 7 is within a rectilineal figure which has not been completed, or has been obliterated, towards the right. There has been a considerable recent accretion of stalagmite, which has probably obliterated a portion of the enclosing figure and some of the letters there; thus MARTY has perhaps lost a terminal N.

Not far from the centre of the Chamber a considerable boss of stalagmite rises from the floor of the same material, having on its sides several badly scratched letters, and the following very well cut inscription in characters about an inch high:—

ROBERT HEDGES
OF IRELAND
FEB. 20. 1688.

On account of the attention which this inscription has attracted and the name in it, the mass of Stalagmite has been named "The Hedges Boss." It can scarcely be necessary to say that the Committee have left it so far intact as they found it. The earlier explorers had broken the Stalagmitic Floor all around it, and they, or probably some earlier visitors, seem to have contemplated its removal or destruction; for its apex is broken off, and a hole 7 inches deep has been bored into it, no doubt with the intention of blasting it. In basal circumference it measures about 30 feet; its present mutilated top is about 4 feet high, and the Floor of Granular Stalagmite from which it rises is about a foot thick. It is not possible to believe that Mr. MacEnery countenanced the attempt to destroy the Boss, as he attached much importance to the inscription on it, mentioning it at least four times in his 'Cavern Researches.' The effort may, no doubt, be ascribed to an earlier period, when it is stated by a writer in the 'Monthly Magazine' for June 1805, twenty years prior to Mr. MacEnery's first visit, when the Cavern was open to all comers without let or hindrance, that "attempts have been made to work the stones and spars [in Kent's Hole], but they do not prove ornamental"*.

It is not a little strange that though the name "Robert Hedges" is perfectly legible, Mr. MacEnery not only never so renders it, but actually gives it in three distinct forms; twice he speaks of it as "Robert Hodges"†, once as John Hodgson ‡, and once as "J. Hodges"§. Nevertheless, his description of it is of great value. "The letters," he says, "are glazed over and partly effaced"‖. Again, "The letters in the inscription are overlaid"¶. In short, the terms he applied to it are still perfectly apposite, and justify the belief that the inscription is as old as it professes to be. The drip on it at present is somewhat plentiful in wet weather, and there is no doubt that calcareous matter is still in course of deposition. Of all the characters, the terminal 8 in the date is probably most in danger of obliteration.

It was stated in the Tenth Report (1874) that the exploration of the Cave of Inscriptions had been completed up to 16 feet from its entrance, when, the mouth of Clinnick's Gallery being completely exposed, the investigation of the deposits in the latter branch of the Cavern was undertaken. This, as already mentioned, was carried on until December 1st, 1874, when the work in the Cave of Inscriptions was resumed.

In that portion of this Cave explored in 1874, the Committee found that there were no traces of the presence of their predecessors; that the Granular, or less ancient, Stalagmitic Floor was everywhere intact and continuous, and the Crystalline, or more ancient, Stalagmite lay beneath it; that the latter had been broken by some natural agency, and though in some cases the severed portions remained *in situ*, in others they had been removed and were not always traceable; and that adjacent to the left wall of the Cave a wedge-like layer of Cave-earth lay in its proper place between the Stalagmites, and was 6 inches thick at the wall, but thinned out at about a yard from it, beyond which the one Floor lay immediately on the other. This continued to be the case to a large extent for the next 18 feet (that is, up to 34 feet from the entrance), the only exception being that the broken blocks of Crystalline Stalagmite were never dislodged beyond being occasionally "faulted" to the extent of 2 or 3 inches. At and beyond 34 feet from the entrance, traces of the earlier explorers were again met with in almost every part of the Cave, but were found to be limited to the breaking up of the Stalagmites and of the subjacent deposit to the depth of 12 inches at most. A thin layer of typical Cave-earth extended throughout the entire Chamber; and it was obvious that at the time when its deposition commenced the Crystalline Stalagmite did not exist as a continuous sheet, for in considerable spaces the Cave-earth lay immediately on the Breccia without any Stalagmite between them. Though it was not always easy in these cases to determine the exact junction of the two deposits, there was no doubt that the upper surface of the Breccia was very uneven when the Cave-earth began to be lodged on it. On the discovery of objects of interest at or near this doubtful junction, care was taken to record them as belonging to the "Cave-earth and Breccia," even though, from their own characters, it was usually easy to refer them to their proper deposits and eras respectively. Large blocks of limestone, some of them requiring to be blasted, were numerous in this Cave, both in the Stalagmites and below them.

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* Monthly Magazine, London, vol. xix. p. 435.

† See 'Trans. Devon. Assoc.' vol. iii. (1869) pp. 275 and 459.

‡ Ibid. p. 314.

§ Ibid. p. 459.

‖ Ibid. p. 275.

¶ Ibid. p. 459.

On its excavation being completed, the Cave of Inscriptions was found to extend upwards of 60 feet from north-east to south-west, 45 feet from south-east to north-west, and to be upwards of 20 feet high. In the right wall, immediately before reaching the Hedges Boss, there is a recess to which the name of "The Alcove" has been given; another, in the north-western corner, probably leads to an external entrance to the Cavern: in the south-west corner is the mouth of the long tunnel known as the "Great Oven;" and adjacent to it is a Gully about 3 feet wide at the entrance, and extending to an unknown distance but too narrow for exploration beyond a length of 7 feet.

Two "finds" only were met with in the Granular Stalagmitic Floor: one (No. 6491) consisted of a few bones, including a portion of a large humerus; the other (No. 6495) was a very small bone, probably of Bat, with bits of charcoal and of coprolite, all lodged in the same hand specimen of Stalagmite, and found 3rd December, 1875.

The Cave-earth yielded 4 teeth of Hyæna, a few gnawed bones, coprolites on several occasions, and 1 flint flake (No. 6520).

At and near the junction of the Cave-earth and Breccia, where they were not separated by Stalagmite, 2 right lower jaws and 4 loose teeth of Hyæna, 38 teeth of Bear, part of a jaw of Fox, 1 incisor tooth of a small rodent, numerous bones and fragments of bone, a somewhat large number of coprolites, and 1 flint flake were met with. At least, most of the ursine remains may be safely referred to the Breccia, whilst all those of the Hyæna undoubtedly belong to the Cave-earth. One of the Hyæna-jaws just mentioned

(No. 6570) contains all its teeth except the inner incisor; but, as is commonly the case with lower jaws of the era of the Cave-earth, it has lost its lower border and condyles, and is much gnawed. It was found 14th May, 1875, with 1 loose canine tooth of the same species, 4 teeth of Bear, and a few fragments of bone. The other jaw of Hyæna (No. 6577) has lost the two inner incisor teeth and the condyles, and is slightly gnawed, but is otherwise entire. It was found on 24th of the same month, with 1 loose tooth of Hyæna, 1 of Bear, and a fragment of bone. The flint flake (No. 6582), found 1st June, 1875, probably belonged to the Breccia, but was of but little importance.

There were found in the Breccia 82 teeth of Bear, some of them in jaws or parts of jaws; 2 of Lion, in a portion of right upper jaw; numerous bones and pieces of bone, including part of a skull and several other good specimens; and 13 implements, flakes, and chips of flint and chert (Nos. 6525, 6532, 6540, 6547, 6550, 6552, 6561, $\frac{1}{6562}$, $\frac{2}{6562}$, 6565, 6573, 6581, and 6590). The Lion's teeth (No. 6518) are the last two molars. The sockets of the canine tooth and of the small tooth immediately behind it still exist, and every thing betokens an animal of great size. The specimen, to which a considerable quantity of the Breccia adheres, is peculiarly interesting as being found in a deposit in which careful methodical research, continued for years, had failed to detect any other osseous remains than those of Bear, with but one exception—that, as already stated, being also the lower jaw of a Lion, found less than two months before. This interesting relic was met with on 31st December, 1874, with 2 teeth of Bear, bones and fragments of bone, in the second foot-level of Breccia. No feline remains have been detected since that date.

A few only of the Flint and Chert specimens require detailed description.

No. 6550 is an implement made out of a well-rolled chert nodule. It is somewhat semilunar in form, but broader at one end than the other, and measures about 4·4 inches in length, 2·3 inches in greatest width, and 2·5 inches in greatest thickness, which it attains near the broader or but-end. It has undergone a considerable amount of chipping, has been reduced to an irregular edge along the greater part of its perimeter, and is comparatively thin at the more pointed end. It is very, but unequally, convex on both faces, each of which has a central ridge, and retains the original surface of the nodule over the whole of the but-end, whence a trace of it extends along the central ridge of the less convex face to about an inch from the point. The portion of the surface which has been chipped is of a yellowish hue, derived, no doubt, from the matrix in which the specimen lay. This, however, is but a superficial stain, as there are indications of an almost white colour within. This fine implement was found 15th February, 1875, between the Hedges Boss and the left wall of the Cave, 36 feet from its entrance, in the second foot-level below the surface (that is, in the uppermost foot-level of the Breccia), having no other object of interest near it.

No. 6565 is a chert implement 3·7 inches long, 2·7 inches in greatest breadth, and 1·7 inch in greatest thickness, which it attains not far from its centre. It has unfortunately lost one of its extremities, apparently broken off whilst the tool was being made. It is very, perhaps equally, convex on each face, but the centres of convexity are not opposite one another; and though obviously made from a nodule, not a flake, no part of the original surface remains. A considerable amount of work has been expended on it, and it has been reduced to an edge all round the perimeter except at the broken end. The marginal edge is neither keen, nor regular, nor in the same continuous plane. There can be little doubt that it was intended to be a somewhat pointed ovoid tool, and that had it been perfected it would have been more symmetrical in form than the Breccia tools are usually. Its colour is whiter than that of most of the implements found in the same deposit, in which respect, as well as in its shape and the absence of any trace of the original surface, it closely resembles the implement No. 6103, found in the "Long Arcade," 7th May, 1873, and described in the Ninth Report (1873). This specimen was met with on 13th April, 1875, in the second foot-level of the Breccia, without any other object of interest near it, 47 feet from the entrance of the Cave of Inscriptions.

No. 6581 is a flint flake, struck from a rolled nodule, round at one end, abruptly truncated at the other, and reduced to an edge along both lateral margins. It is 2·2 inches in greatest length, 1·6 inch in greatest width, and ·6 inch in greatest thickness. The inner surface is very irregular; the outer has three longitudinal facets; the lateral margins are somewhat sharp but slightly jagged as if from use; both ends are blunt, and the "but" retains the original surface of the nodule. Its colour is the warm yellow so characteristic of most of the specimens found in the Breccia; but there are indications that the interior is white. It was met with on 29th May, 1875, in the second foot-level of the Breccia, 57 feet from the entrance of the Chamber.

The Gully in the south-west corner of the Cave of Inscriptions, already mentioned, was so narrow as to render it impossible to excavate the deposits occupying it in "parallels," "levels," or "yards." The specimens found in it, however, were only 2 teeth of Bear, a few pieces of bone, and a coprolite.

The earlier explorers had, as usual with them, imperfectly examined the material they dug up in this branch of the Cavern, and then thrown it on one side. On taking it to the daylight the Committee found in it 19 teeth of Bear, 12 of Fox (of which 10 occupied portions of three lower jaws), 9 of Hyæna (two of them being in part of a lower jaw), 2 of Horse, and 1 of Rhinoceros, and a large number of bones (some entire but most of them fragmentary), numerous coprolites, a fragment of a marine shell, and 6 flakes and chips of flint.

The exploration of the Cave of Inscriptions was completed on 14th June, 1875, having occupied the labour of between 8 and 9 months.

The following is a list of the specimens found in it in undisturbed ground, inclusive of those mentioned in the Tenth Report (1874):—

In the Granular, or least ancient, Stalagmitic Floor: 1 bone of Bat (?), a few bones, a few patches of coprolite, and a bit of charcoal.

In the Cave-earth: 27 teeth of Hyæna, several of them in jaws or parts of jaws; 11 of Bear; 1 of a small rodent; 1 jaw of Fox; numerous bones and fragments of bones, of which 6 had been charred and still more had been gnawed; a large number of "finds" of coprolites; and 7 tools, flakes, and chips of flint and chert.

In the Breccia: 321 teeth of Bear, some of them in jaws and parts of jaws; 2 of Lion, in parts of an upper jaw; and 20 implements and flakes of flint and chert.

The Recess.—On completing the exploration of the Cave of Inscriptions, operations were at once commenced in the Recess occupying its north-western corner, which, as already stated, was expected to lead to a new external entrance to the Cavern. The following are the grounds on which this expectation was founded:—At the entrances at present known, on the eastern face of the Cavern hill, and termed the "Triangular" and the

"Arched" entrances, the Cave-earth, or least ancient of the two great mechanical accumulations, is at a high level and of great depth. Thence it slopes rapidly downwards in all directions open to it, and at the same time decreases in depth, until reaching the remote end of the "Lecture Hall" towards the south and the bottom of the "Sloping Chamber" towards the west. From these facts it has been concluded that the Cave-earth entered the Cavern through the existing and known entrances. Beyond the foot of the slopes just mentioned, the levels are found to be no longer governed by the Cave-earth but by the Breccia (that is, the underlying or more ancient deposit); and there is in each case an acclivity, instead of a declivity, on proceeding further and further into the Cavern—comparatively short and abrupt from the Lecture Hall to the Water Gallery on the east, but long and gentle from the Sloping Chamber to the Recess, now under notice, on the west. These acclivities apparently indicate that the Breccia entered the Cavern not, like the Cave-earth, through the apertures on the eastern side of the hill, but through an opening or openings on the western side; and the same line of argument points out the Recess in the north-western corner of the Cave of Inscriptions as more likely than any other part of the Cavern to lead to such an external entrance. So far as they can be studied, moreover, its own characters support this hypothesis. The Recess extends in a north-westerly direction for fully 60 feet, and is of sufficient width for a man to pass easily; beyond this its extent is considerable, but at present is too narrow for any one to examine it. Its Floor, a thick sheet of the Crystalline, or more ancient, Stalagmite, is abruptly truncated at the junction of the Recess with the Cave of Inscriptions. Finally, this Floor covered and rested on a thick mechanical accumulation, which is unmistakable Breccia and reached a higher level than elsewhere in the Cavern, so far as is known at present.

The exploration of the Recess was begun on 15th June, 1875; and as it was decided to leave intact the Stalagmite Floor just mentioned, in fact to burrow under it, it was necessary to cut the successive "parallels" 5 feet deep instead of the usual 4, in order to give the men height enough for working. During the progress of the work a hole was bored through the Floor overhead, when it was found to be pure Stalagmite, 18 inches thick. When the excavation had reached a distance of 10 feet, the two walls were found to be so very nearly together as to render it necessary to abandon the work, or to break up the Floor and proceed at a higher level. The former course being, though reluctantly, decided on, the work was suspended on 6th July, 1875.

The only objects of interest found here were 2 teeth of Bear, 3 "finds" of bones, and 1 piece of flint (No. 6590) of no importance.

The Alcove.—The exploration of the Alcove or recess near the Hedges Boss, already mentioned, was begun on 7th July, 1875, and finished on 26th of the same month, or at the end of about 3 weeks. When emptied, it proved to be scarcely lofty enough, from limestone floor to limestone roof, for an ordinary man to stand erect, to measure about 10 feet both from north to south and from east to west, to be divided into two compartments, a northern and a southern, by a limestone partition extending almost completely across it, and to have two entrances from the Cave of Inscriptions. The earlier explorers had partially ransacked the northern compartment, but had not entered the southern, in which a Floor of Stalagmite almost reached the roof. Beneath this Floor, and without any trace of Cave-earth, lay the Breccia, never exceeding 3 feet in depth, and resting on the limestone floor.

39 " finds " of remains of Mammals were met with in the Alcove, including 59 teeth of Bear (several of the min portions of jaws), 16 of Fox (all of them in portions of three lower jaws), 4 of Hyæna, numerous bones (including several good specimens, though all of them were more or less fragmentary), and 1 coprolite. The teeth of Hyæna, 2 of the jaws of Fox, and the coprolite were met with at the junction of the northern compartment and the Cave of Inscriptions, amongst fallen masses of limestone, where neither the character of the deposits nor the exact position of the specmiens could be determined. The remaining jaw of Fox, however (No. 6619), was found in the Breccia; it was broken into two pieces, which lay together and contained 5 teeth. This specimen, the only known relic of the genus in this old deposit, was found at the inner or eastern end of the southern compartment, in the second foot-level of Breccia, with remains of Bear, 17th July, 1875. It may not be out of place to remark that remains of the Common Fox (*Canis vulpes*) have been identified among the Mammalian relics from the Forest-bed underlying the Boulder-clay on the coasts of Norfolk and Suffolk *.

In proportion to the volume of the deposit it contained, the Alcove was far richer in osseous remains than any part of the Cave of Inscriptions, of which it is an adjunct. It is worthy of mention, perhaps, that it contained no trace of flint or chert.

The Great Oven.—The passage or tunnel opening out of the south-west corner of the Cave of Inscriptions is very long and narrow, and so low that a considerable portion of it can only be traversed on all-fours or in a crouching posture. It connects the Cave of Inscriptions with the "Bear's Den," which the Committee have not yet explored, and has been termed the "Oven," partly from its very contracted breadth and height, but mainly because a vertical section of a considerable part of it at right angles to its length closely resembles the small earthenware ovens much used formerly in the two south-western counties. It has received the epithet *Great* to distinguish it from a similar but still more contracted tunnel in another part of the Cavern, and known as the "Little Oven."

The excavation of the Great Oven was begun 27th July, 1875, and at the end of that month, beyond which this Report does not extend, it had been completed to 4 feet from the entrance. Like the Cave of Inscriptions, it contains a thin layer of Cave-earth, with Breccia beneath it of unknown depth. Two " finds " have been met with in the former, containing 1 tooth of Hyæna and a few bones; and 9 in the latter, including 6 teeth of Bear and several pieces of bone.

On studying the osseous remains found by the Committee in the Breccia in the various branches of the Cavern they have explored during the last twelve months, the following prominent facts arrest attention:—Some of the teeth of Bear are those of very old animals, and worn almost to the fang, such as No. 6597 from the second foot-level, No. 6608 from the second foot-level, No. 6611 from the fourth foot-level, and No. 6618 from the second foot-level, all found in the southern compartment of the Alcove during July 1875. The jaws, though frequently broken, have never lost their lower borders, as is almost uniformly the case with the Cave-earth specimens; and none of the bones appear to have been gnawed. In no instance were the bones found lying in their anatomical relations, but different parts of the skeleton were often huddled confusedly together; thus in No. 6613, found in the second foot-level in the southern compartment of the Alcove, 15th July, 1875, a canine tooth adheres to one side of the proximal end of a tibia, and a piece of jaw to another side. Some of the specimens have fretted surfaces, and appear to have been rolled by running water; this is notably the case with Nos. 6608 and 6615, found in the second and first foot-levels, in the southern compartment of the Alcove, on 12th and 16th July, 1875, respectively. Many of the bones were broken where they were finally lodged, and the parts, with little or no displacement, reunited with Stalagmitic infiltration; as, for example, Nos. $\frac{1}{6618}$ and $\frac{2}{6618}$, found in the first foot-level in the branch of the Cavern just named, 17th July, 1875. Others appear to have been flattened and more or less crushed where they lay, of which there is a striking example in the distal end of a left femur, No. 6530, found in the first foot-level in the Cave of Inscriptions, 34 feet from its entrance, 12th January, 1875. Occasionally the same rock-like mass of Breccia contains bones of very different colours; thus No. 6603 is such a mass, containing portions of two bones not half an inch apart, each accidentally broken across; and whilst one is of a creamy whiteness throughout, the other is a very dark brown, approaching to black. It was found in the second foot-level in the Alcove, 9th July, 1875. This specimen, by no means unique, shows that contemporary bones lying side by side may be of very different colours.

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* See 'Cave Hunting.' By W. Boyd Dawkins, M.A., F.R.S., F.G.S., F.S.A. 1874, p. 418.

Nor are the remains met with in the Cave-earth void of instruction. Up to the present time, wherever the Cave-earth has been met with, there also have traces of the Hyæna been found, either in the form of parts of his skeleton, or his coprolites, or bones scored with his teeth-marks, or jaws divested of their lower borders, or long bones broken after his well-known and recognizable fashion. But though everywhere present in greater or lesser numbers, these traces became less and less plentiful with increased distance from the external entrances to the Cavern, and were very "few and far between" in the Cave of Inscriptions—the Chamber most remote from the entrances. Whilst the remains of the Hyæna were thus met with wherever the Cave-earth occurred, they were in the interior accompanied by those of very few of his contemporaries. Thus, whilst the Chambers adjacent to the entrances contained teeth and bones of Horse, Rhinoceros, Deer (several species), Bear, Fox, Elephant, Ox, Lion, Wolf, and Hare, as well as Hyæna (the latter being far the most prevalent), there have been found during the last twelve months in the Cave-earth remains of the Hyæna alone. Nor is it without interest to note the branches of the Cavern in which remains of the different forms just enumerated were last detected, so far as is at present known, on the way to the Cave of Inscriptions. The Hare has not been found anywhere in the Western Division of the Cavern—that of which the Cave of Inscriptions is the innermost Chamber; the Badger, Wolf, and Ox were represented in the "Charcoal Cave," but not beyond it; and relics of Horse, Rhinoceros, Deer, Bear, Fox, Elephant, and Lion have not appeared beyond the Long Arcade.

Finally, no traces of *Machairodus* have been met with since the incisor tooth found 29th July, 1872, and described in the Eighth Report (1872), presented at Brighton.

Seventh Report of the Committee, consisting of Sir W. THOMSON, *F.R.S.*, Professor EVERETT, Sir CHARLES LYELL, *Bart.*, *F.R.S.*, Professor J. CLERK MAXWELL, *F.R.S.*, G. J. SYMONS, *F.M.S.*, Professor RAMSAY, *F.R.S.*, Professor GEIKIE, *F.R.S.*, JAMES GLAISHER, *F.R.S.*, Rev. Dr. GRAHAM, G. MAW, *F.G.S.*, W. PENGELLY, *F.R.S.*, S. J. MACKIE, *F.G.S.*, Professor HULL, *F.R.S.*, Professor ANSTED, *F.R.S.*, *and* Professor PRESTWICH, *F.R.S.*, *appointed for the purpose of investigating the Rate of Increase of Underground Temperature downwards in various localities of Dry Land and under Water*[*]. *By* Professor EVERETT, *D.C.L.*, *Secretary*.

A FEW weeks after the reading of last year's Report, another set of observations was received from Messrs. Mauget and Lippmann, the engineers of the great artesian well now sinking at La Chapelle, Paris. The water had been undisturbed for a year, this time having been occupied in preparations for tubing the well through its entire depth.

The exceptionally rapid increase of temperature in the lower part of the well, as indicated in the previous observations, had given reason to suspect that the heat generated by the action of the boring-tool was an important disturbing element. It is now manifest that this suspicion was correct; for the bottom temperature (660 metres deep), which was 83°·25 Fahr. in the observations of June 1862, is only 76° Fahr. in the observations of October 1863, or 7¼° colder than before. At the depth of 600 metres the temperature was 75°·8 and 75°·4 in the two observations of June 1862, and 75° in the observation of October 1863, or about half a degree colder than before.

At the depths of 500 metres and 400 metres there was no change; and at the depths of 300 metres, 200 metres, and 100 metres there was an increase amounting to 0°·5 at 300 metres, 0°·8 at 200 metres, and 1°·5 at 100 metres.

In explanation of the increase at these smaller depths, Messrs. Mauget and Lippmann remark:—"When last year's observations were made the well had been tubed to the depth of 139·15 metres, but had not been cemented. Consequently the springs which were met with in the tertiary strata communicated at the base of the tubes with the water of the well. Cement has this year been poured in between all the tubes some days before taking the temperature of the water. This operation has excluded the tertiary springs and permitted the water of the well to resume its normal temperature."

The new temperature 59°·5 at 100 metres, combined with the new temperature 76° at 660 metres, gives 1° Fahr. for 34 metres, or for 111 feet.

The old temperature, 58 at 100 metres, combined with the new temperature 76° at 660 metres, gives 1° Fahr. for 31 metres, or for 102 feet.

The temperature 53°·1 in the caves of the Paris Observatory, at the depth of 28 metres, combined with the temperature 76° at 660 metres, gives 1° Fahr. in 27·6 metres, or in 90·5 feet.

All these results differ largely from previous determinations of the rate of increase in the neighbourhood of Paris, which were very harmonious among themselves, and gave a rate of 1° Fahr. in 56 feet (see 1871 Report).

The only source of error that appears possible in the La Chapelle observations is convection by vertical currents in the well. Such action is certainly favoured by the large diameter of the well (1·35 metre at the smallest), and may have been further promoted by the same cause which stopped the works and rendered tubing necessary—namely, caving in.

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[*] Read at the Belfast Meeting, 1874.

Herr Johann Grimm, Director of the School of Mines at Przibram in Bohemia, has furnished some valuable results from observations made by himself in the year 1830, and again in 1854–55, in the deepest mines of that district.

The observations in 1830 showed a temperature 11°·9 R. at a depth of 1127·4 Austrian feet, as against a temperature 7°·34 at 66 feet. The difference here is 4°·56 R. in 1061·4 Austrian feet, or 10°·26 Fahr. in 1100 English feet, which is at the rate of 1° Fahr. in 107 English feet.

The observations in 1854–55 showed a temperature of 13°·08 R. at a depth of 1832·3 Austrian feet, as against 7°·05 R. at 66 feet. The difference here is 6°·03 R. in 1766·3 Austrian feet—that is, 13°·57 Fahr. in 1832 English feet, which is at the rate of 1° Fahr. in 135 English feet.

The following is a tabular statement of the results obtained at different depths in the observations of 1854–55 :—

Name of Gallery.	Depth below shaft-brace. Austrian feet.	Temp in deg. Réaum.	Depth in English ft.	Temp. in deg. Fahr.
Joseph Maria	66·0	7·05	68	47·9
3rd Maria	288·6	7·45	299	48·8
7th Adalbert	599·3	8·30	621	50·7
9th „	904·8	11·45	939	57·8
13th „	1244·4	11·70	1209	58·3
17th „	1362·8	12·20	1414	59·4
19th „	1591·9	12·98	1652	61·2
21st „	1832·3	13·08	1900	61·4

Taking the differences of successive numbers in the last two columns, we deduce the following rates of increase :—

In the first	68 feet	Unknown.
In the next	231 „	1° per 260 feet.
„	322 „	1° per 170 „
„	318 „	1° per 45 „
„	351 „	1° per 700 „
„	124 „	1° per 110 „
„	238 „	1° per 132 „
„	248 „	1° per 1400 „
	1900	

If we had omitted the last 248 feet from the reckoning, the average rate of increase would have been 1° for 120 feet.

The following explanatory remarks are extracted nearly verbatim from Herr Grimm's letters :—

"The depths of the shafts in these mines, and specially of the Adalbert and Maria shafts, you can see from the annexed Table [Section annexed, showing fifteen shafts]. The Adalbert shaft is sunk perpendicularly to the depth of 470 Vienna fathoms = 891·5 metres from the shaft-brace to the bottom of the shaft.

"I have to remark that, for the observations of the temperatures, such levels and places were selected as were far from the workings and from all circumstances which could cause a change of the temperature of the rock. The temperature was observed on thermometers put in bore-holes of 2 feet depth, which were bored in idle rock free of any particles of iron pyrites and far from all lodes. Through the whole time of the experiment, in summer and winter, the temperature of the rock on each level remained, excepting only some very small variations, nearly without change.

"From the Table it will be seen that the increment of heat by descending in the mines is much smaller than in the mines of other localities. The reason of it may be looked for in the quality of the rock, which, belonging to the beds of the Lower Silurian formation, is very quartzose and free of any particles of iron pyrites.

"The temperature in the bore-hole remained, by the observations made throughout the whole year 1830, without a change, as the bore-hole (which was closed up with a piece of clay) kept always the equal temperature of the rock. Even in the year 1854–55, when the observations in the higher levels were repeated and the same bore-holes used, the temperature remained the same.

"The shaft-braces of the different shafts differ very little in height, as you have seen from the sketch sent to you, and all of them are situated on lofty hills. My observations of the increase of heat have all been made near the Adalbert shaft, on the different levels; and the difference from the temperature on the same levels in the other mines can only be trifling."

These observations appear to be thoroughly reliable, and to prove conclusively that the rate of increase in this locality is remarkably slow. Even after applying a large conjectural correction for the convexity of the ground, as connected with the fact above stated that all the shaft-braces "are situated on lofty hills," the rate of increase will still remain slower than any that we have hitherto discussed. From the description of this rock, considered in connexion with the description given of the rocks in the Mont-Cenis Tunnel (1871 Report), it would appear that highly quartzose rock is characterized by a slow rate of increase—an index probably of high conductivity*.

Further observations will be taken by Herr Grimm with two thermometers which have been supplied to him by the Committee. One of them is a maximum protected Negretti, the other a simple mercurial thermometer with a large bulb.

Several instruments of this latter kind have been constructed for the Committee during the past year, with a view to observations similar to those above described by Herr Grimm. The objects aimed at in the construction are, slowness of action, combined with facility for reading with quickness and certainty in a bad light.

It was stated in last year's Report that M. E. Sadoine, Director-General of the mines of the Société Cocqueril at Seraing, near Liège, had consented to have observations taken in the mines of that company. A Negretti maximum thermometer was accordingly sent in September 1873, and at a later date (March 1874) a non-registering unprotected thermometer. The following results, obtained with the maximum thermometer, have been communicated by the chief engineer of the collieries. The observations were made in December 1873.

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* Added September 1875. This inference as to the high conductivity of quartz, published a year ago, is verified by the direct experiments of Professor Herschel (see Report on Conductivity of Rocks in the present volume). Quartz was found to be the best conductor of all the rocks experimented on.

Name of Colliery.	Depth in metres.	Temperatures Fahrenheit. Surface.	Air in gallery.	Rock in hole.
Marie	232	59°	78°	77°
Do.	310	56	77	78
Henri Guillaume	505	45	77½	87

The site of the two collieries in question is on the banks of the Meuse. The observations were made at the bottom of holes 5 centimetres in diameter and 5 metres deep, bored at the ends of galleries 6 feet high and 6 feet wide, the material of the rock being coal-schist (*des schistes houillers*). The thermometer remained in each hole twenty hours. The holes at the depths of 232 metres and 310 metres are almost vertically beneath the bed of the river. The hole at the depth of 505 metres is about 900 metres from the river. The coal-bearing strata are covered with 8 or 10 metres of gravel, in which the bed of the river is contained.

Comparing the first and last of the above observations, we have an increase of 10° Fahr. in 273 metres, which is at the rate of 1° Fahr. in 27·3 metres, or in 90 feet.

The temperature of the ground near the surface can be approximately inferred from Quetelet's observations at Brussels, which is about 50 miles distant from Seraing, and about 10 miles further north. Quetelet found the ground, both at the depth of 12 feet and of 24 feet, to have a mean annual temperature of 12° Cent., or 53°·6 Fahr. If we accordingly assume at Seraing a temperature 54° Fahr. at the depth of 5 metres, we have, by comparison with the temperature 87° at 505 metres, an increase of 33° in 500 metres, which is at the rate of 1° Fahr. in 15·2 metres, or in 50 feet.

It was mentioned in the 1872 Report that four thermometers had been sent to the School of Mines at Ballarat, Australia. A communication has recently been received from the Vice-President (his Honour Judge Rogers), enclosing a report of observations taken at Clunes, in the mine of the New North Clunes Company, by Mr. John Lewis (the Company's general manager), and promising a report of observations from the Stawell Mine by an early mail. Both mines are about 1000 feet deep.

Mr. Lewis's observations were taken in twelve bore-holes, each 3 feet deep, which were filled with water four or five hours previously, and the thermometer (a large non-registering mercury thermometer) was allowed to remain in the hole for thirty minutes before reading. The depths from the surface of the ground vary from 160 feet to 1015 feet. It appears that sufficient precautions were not taken to exclude atmospheric influences, by plugging the holes and avoiding places where the currents of ventilation were strong. The temperatures recorded in all the bores, except one, appear to be thus vitiated, and are very variable from time to time.

The one bore to which these remarks do not apply is designated "bore No. 10," is at a depth of 790 feet from the surface, and is described as "being in a cross cut without any circulation of air." The temperatures observed in it, in the four observations recorded, were 72°·6, 72°·5, 72°·5, and 72°·5, the temperature of the air in its vicinity being 73°·6, 73°, 73°, and 73°.

Mr. Symons has furnished additional observations made at the depth of 1000 feet in the Kentish-Town well, but recommends that their publication be deferred for the present, as better observations are expected during the ensuing year. The hut which covers the well has been repaired, and the apparatus employed in the observations has been thoroughly cleaned and put in order.

In answer to an application addressed to the director of the School of Mines at Schemnitz, in Hungary, a letter was received, under date November 1873, from Herr E. Poschl, Counsellor of Mines, and Professor of Mining Mechanics and Drawings (the director being absent), requesting that thermometers might be sent. A second letter was received from the same gentleman, dated December 26, 1873, acknowledging the safe arrival of the thermometers (one a Negretti maximum protected, the other non-registering and unprotected), and stating that the observations would at once be commenced, under the direction of a joint committee of professors of the Mining Academy and members of the Directory of Mines.

Professor Henry, of the Smithsonian Institution, Washington, wrote, under date February 3, 1874:—"You will oblige us by sending us three sets of guarded registering thermometers, suitable for observations of temperature of artesian wells of a diameter of 3 inches. We learn that there are in the vicinity of Chicago sixty wells varying from 500 feet to 1500 feet in depth, included within an area of six miles square. Their elevation above the level of Lake Michigan, as well as the quality of the water they furnish, are very nearly alike. We shall send a set of these instruments to a trustworthy engineer of Chicago." . . .

In accordance with this request, three protected maximum thermometers have been sent.

No successful observation has yet been made in the Sub-Wealden bore nor in the well at Witham. No report has been received from Harwich, from Anzin, from the Hoosac Tunnel, nor from the Mont-Cenis Tunnel.

As regards the St.-Gothard Tunnel, the absence of Professor Ansted has hitherto delayed the carrying out of the resolution adopted by the General Committee last year (see Report for 1873, p. lviii, last paragraph); but action will probably be taken very speedily.

Report of the Committee, consisting of Professor HUXLEY, *F.R.S.*, P. L. SCLATER, *F.R.S.*, F. M. BALFOUR, J. GWYN JEFFREYS, *F.R.S.*, Dr. M. FOSTER, *F.R.S.*, E. RAY LANKESTER, *F.R.S.*, *and* A. G. DEW-SMITH (*Secretary*), *on the Zoological Station at Naples.*

AT the Bradford Meeting of the Association the Committee on Zoological Stations was able to report (see Association Reports, 1873, page 408) that the building of the Zoological Station at Naples had been completed; but it was naturally obliged rather to describe the arrangements made for carrying out the objects of the Station than to dwell on the work which had been actually done.

The present Committee, however, can now congratulate the Association that, during the two years which have elapsed since the Bradford Meeting, a scientific undertaking of cosmopolitan character, in which the Association has taken a lively interest, and which it has in so many ways assisted, has proved an undeniable, indeed it might be said a brilliant success. The actual difficulties and obstacles have, no less through the great energy of Dr. Dohrn than through the help afforded him from time to time, been overcome; and the future of the Station seems in every way bright and promising.

The facts which form the subject of the present Report will best be considered under distinct heads:—

1. *The Nature and Extent of the working accommodation at the Station.*

At the present time there are in the Station twenty-one working-tables, the number of which will by the end of the year be increased to twenty-four; of these no less than seventeen are already occupied or bespoken.

Each table is in itself a condensed laboratory; and the nature of the accommodation offered by the Station to any investigator will perhaps best be shown by the following extract from the form of contract between Dr. Dohrn and the hirer of the table.

a. The working-table, fully equipped, will be placed at the disposal of the inquirer nominated to occupy it after the interval of a week from the announcement of his coming.

The equipment consists of:—

1. The necessary chemical reagents.
2. The ordinary anatomical and microscopical tools and apparatus.
3. Drawing-apparatus.

In detail these are as follows:—

Reagents.

Alcohol, 70 per cent.
,, 90 per cent.
,, absolute.
Distilled water.
Müller's fluid.
Potassic bichromate, 5 per cent.
Calcic chloride.
Potassic acetate.
Alum.
Gold chloride, 1 per cent.
Silver nitrate, 1 per cent.
Chromic acid.
Perosmic acid.
Hydrochloric acid, pure.
Acetic acid (concentrated).
Picric acid.
Oxalic acid.
Nitric acid (concentrated).
Sulphuric acid (concentrated).
Caustic soda.
Caustic potash.
Caustic ammonia.

Olive-oil.
Pure fat.
Turpentine.
Oil of cloves.
Creosote.
Chloroform.
Ether.
Glycerine.
Tincture of iodine.
Berlin blue solution.
Canada balsam.
Gum-arabic.
Beale's carmine solution.
Hæmatoxylin solution.
,, ,, alcoholic.
Magenta.
Picrocarmine.
Cement.
Wax.
Paraffin.
Spermaceti.

Instruments.

Section-cutting knife.
2 pairs forceps.
3 pairs scissors.

3 scalpels.
2 preparation-needles.
2 dozen needles.

Drawing-Apparatus.

1 Drawing-tablet.
6 Drawing-pins.
4 Drawing-pencils.
Blotting-paper.
Colour-box and brushes.
Rule.
Drawing-instruments.
3 gold pens.
Ink eraser.

Glass Instruments.

1 dozen simple glass slides.
1 large hollowed glass slide.
1 small oval hollowed glass slide.
1 trough object-holder.
50 thin cover-glasses.
1 lamp.
1 measure-glass.
1 pipette.
3 glass tubes.
3 glass rods.
6 stoppered bottles.
1 wash-bottle.
1 tray with reagents.
3 beakers.
5 glass plates.
1 microscope-shade.
1 instrument-shade.

Miscellaneous.

2 porcelain capsules.
3 paint-saucers.
1 dozen filter-papers.
1 preparation-trough.
1 can.
1 washing-basin.
2 towels.
1 slate.
India-rubber tubes.
2 portable tanks for holding smaller animals.

The Station also possesses:—

a. A number of special instruments and pieces of apparatus which are not in general use, but only required occasionally. These accordingly are not supplied to each table, but are regarded as belonging to all the tables in common.

Microscopes are *not* provided, it being supposed that each investigator will possess an instrument of his own, to the use of which he is accustomed.

b. Each working-table is provided with a number of working experimental aquaria, and with a constant stream of sea-water; these are entirely at the disposal of the occupant of the table for his investigations.

c. The animals serving as materials for study are provided by the Station, and as constant a supply as circumstances will admit is kept up during the investigation. Not only so, but the occupant of the table can, if he pleases, take home with him, on his departure from Naples, a number of scientifically preserved specimens, to enable him to complete or continue his research.

The extent of this supply of animals is of course dependent on the variety (or abundance) of the specimens and the concurrent demands of other investigators.

d. The large aquarium of the Station can be used freely by the occupants of tables for suitable purposes; for instance, for the study of the habits of animals.

e. The Library * (the catalogue of which has been sent to all academies and universities), placed close to the Laboratory, is accessible to all occupants of tables. There is also a separate room for making extracts and preparing MSS.

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* The Library has already, even in so short a time, become a fairly extensive one, being especially rich in embryological works. A copy of the Catalogue may be seen in Siebold and Kölliker's 'Zeitschrift,' Bd. xxv. Dr. Dohrn will thankfully receive additions,

f. The laboratory is open at 7 A.M. in summer and 8 A.M. in winter. In particular cases special arrangements can be made for access at unusual hours; but the staff cannot undertake to have the Laboratory cleaned before the above-mentioned times.

g. Any occupant of a table is free to accompany and take part in the fishing- and dredging-expeditions of the Station. He may thus learn the use of the dredge and the towing-net and the other means employed for procuring specimens.

h. The cost of the ordinary wear and tear of the instruments and apparatus is borne by the Station to the extent of 20 francs. Damages to a greater extent than this must be paid for by the occupant of the table.

The working-tables thus equipped and disposed in several rooms constitute *the Laboratory* of the Station; and of these, of course, the interest and importance are purely and exclusively scientific.

The large aquarium on the ground-floor has, on the other hand, a double function. It is partly a popular exhibition, and the payments of visitors constitute a not inconsiderable and, it is to be hoped, an increasing item in the income of the Station. It serves also as a large field of observation for scientific investigators desirous of learning something about the habits of animals.

When our great ignorance on this subject is considered, in relation to the morphological importance with which the theory of natural selection and descent has invested even apparently small details of the working of animal economies, the large aquarium may, after all, seem no less a laboratory than the working-table.

It will of course be understood that the general public, who are admitted on payment to view the large aquarium, are carefully excluded from the laboratories proper, though the occupants of tables in the latter have free access to the former.

The staff of the Station consists of:—

a. Dr. Dohrn, the general director.

b. Dr. Eisig, who has direct command of the laboratory, and whose duty it is to superintend all the arrangements of the tables, to arrange for the providing of the material, and to preside over the distribution of instruments and reagents. In Dr. Dohrn's absence Dr. Eisig acts as his substitute.

There are also two other scientific assistants, one to superintend the large aquarium and the fishing, the other to arrange for the collection and preservation of animals for the use of the Station or for distribution abroad.

c. Three engineers, four house servants, and four fishermen.

Such are the general arrangements of the Station for scientific work; and your Committee can report (from the personal experience of two of their number during the past winter) that these arrangements are carried out in a thoroughly satisfactory manner.

2. *The nature of the work for the carrying on of which the Station offers facilities.*

a. Investigations into the morphology and embryology of Marine Animals.—It is needless to say much on this point. The advantages, first, of an organization to secure the animals which it is desired to study, and, secondly, of a laboratory in which to work on the animals thus obtained, are too obvious to require pointing out.

We might, however, remark, as a caution, that the Station cannot provide marine animals which do not visit the neighbourhood of Naples; and moreover, seeing the strange coming and going of particular forms at various times, cannot undertake to provide certain animals at all times.

For instance, the investigator who desires to study *Pyrosoma* must visit Naples at the same time as does the object of his study, otherwise it will be impossible for the Station to procure him living examples.

b. Physiological investigation of Marine Animals.—This branch of stndy, little worked at present, will probably afford rich results in the future.

c. Study of the habits of Marine Animals.—Of the importance of this we have already spoken.

d. Systematic investigation of the Marine Fauna and Flora of the Mediterranean in the vicinity of Naples—In spite of all that has been done in this direction much yet remains to be done. Possibly few tasks seem more promising than a thorough systematic and long-continued dredging of the Bay of Naples and the sea around. The results of such an inquiry would be valuable not only to the systematic zoologist and to the student of the distribution of animal life, but also indirectly to the morphologist and to the Station, as affording certain information as to where and when particular animals may be obtained, and an exact knowledge of the generic and specific nomenclature of the forms studied.

On this head we might call attention to the interesting problems connected with the periodic appearance and disappearance of certain animals in shoals or large numbers—problems which have already attracted the notice of the residents at the Station, and which can only be successfully attempted by long-continued observations at the same place.

Animal forms naturally occupy the chief attention at the Station, but no less facilities are offered for the study of marine vegetable forms. This is sufficiently indicated by the fact that Prof. Cohn, of Breslau, and Dr. Reineke are about to visit the Station next session to carry on algological researches.

e. The Station offers also no mean opportunities for the physical investigation of the sea in the neighbourhood of Naples.

f. Experiments on breeding and preserving delicate Marine Organisms in a healthy vigorous condition.—This subject has already, since the Bradford meeting, especially engaged the attention of Dr. Dohrn; his results, however, are not as yet sufficiently definite to enable him to draw up his promised report, though we hope that it will be ready at the next Meeting of the Association.

g. Transmission of specimens to investigators at home.—Already this work has been carried on, though at present on a small scale. Various investigators have received supplies of animals carefully preserved for the purposes of research. It is proposed, as soon as the fishing arrangements have become more complete, to develop largely this special activity of the Station, so that investigators at home and the authorities of museums may be able to obtain such animals as they may desire in a perfect condition with great ease and at a low price; in fact, at what is to the Station cost price.

3. *The Scientific results of the Station.*

Since the opening of the Station in the early part of 1874 no less than 33 investigators have made use of the Station, the stay of each varying from a few weeks to several months, and some of them having visited the Station during both years.

The following is a list of the names in an approximately correct chronological order:—

1. Prof. Kleinenberg.
2. Prof Waldeyer.
3. Mr. F. M. Balfour (2 years).
4. Mr. A. G. Dew-Smith.
5. Prof. Wilhelm Müller.
6. Prof. Salensky.
7. Dr. Rajewsky.
8. Dr. Steiner.
9. Prof. Henlohe.
10. Prof. Kollman.
11. Dr. Greef.
12. Prof. Ranke.
13. Dr. Hubrecht.
14. Prof. Ray Lankester.
15. Dr. Kossmann.
16. Prof. Hoffmann.
17. Prof. Oscar Schmidt.
18. Prof. Claus.
19. Prof. Selenka.
20. Prof. Langerhans.
21. Prof. Bobretzky.
22. Prof. Rosenberg.
23. Prof. von Ankum.
24. Dr. Götte.
25. Dr. Laurent.
26. Dr. Zincone.
27. Dr. Horst.
28. Dr. Ulianin.
29. Dr. Fanzago (2 years).
30. Mr. A. M. Marshall.
31. Dr. Cavanna (2 years).
32. Dr. Fetter.
33. H. Isnokoff.

Naturally many of the researches undertaken by these gentlemen, especially those made during the past winter, have not yet been published; it is therefore impossible to give any thing like a fair statement of the scientific results of the Station. It would be useless to give a list of those memoirs which have up to the present moment been published, and it would be invidious to pick out any for special comment; but we may say that among the researches, both published and unpublished, are some of very high biological importance, such as would alone justify the application of the word success to the Station.

Next winter Dr. Dohrn proposes to begin a series of annual accounts of the work done at the Station; in fact a sort of scientific almanack of the place, so that the actual research achieved may be made known to all.

4. *The present wants of the Station.*

The large aquarium pays fairly well as a popular exhibition. Since the guide-books have admitted it into their list of things worth seeing at Naples, the number of foreign visitors, English, German, and Russian, has been steadily increasing. Nevertheless the receipts from this source can never be looked upon as a main or a stable source of income. A European war or an epidemic of cholera would in such a case at once put the Station in jeopardy.

It is the money paid by Governments, Universities, and other institutions for the command of the laboratory tables which is to be regarded as the real income.

Of the total 24 tables, 17 are already let; and Dr. Dohrn calculates that when the whole 24 are let λ the Station will be able, with strict economy, to pay its way.

We had intended to make this Report entirely a statement of facts, without adding any suggestions for action; but if we have shown (and we venture to think we have) that the Zoological Station at Naples is doing sound scientific work, and is offering unusual advantages for research to British no less than to German investigators, we may perhaps conclude our Report by suggesting to the consideration of the Association whether it would not be fairly within the scope of its action to undertake the hire of one of these tables. It must be remembered that in this country the University of Cambridge is the only body which is in direct relation with the Station. That University occupies two tables, which it has placed, and naturally will continue to place, at the disposal of its own *alumni*. Hence any British naturalist *not* belonging to the University of Cambridge, and not able to bear of himself the expense of a table, cannot enjoy the opportunities offered by the Station. An equivalent to a grant of £75 per annum would remove the great disadvantage; and we venture to suggest the funds of the Association could not be more profitably spent as far as biological research is concerned.

Report of a Committee, consisting of E. C. C. Stanford, James Dewar, Alfred E. Fletcher, *and* Alfred H. Allen *(Secretary), appointed to inquire into the Methods employed in the estimation of Potash and Phosphoric Acid in Commercial Products and on the mode of stating the results. Drawn up by* Alfred H. Allen.

The Committee was of opinion that the objects for which it was appointed would be best attained by ascertaining as fully as possible the details of the methods of examining phosphates and potash salts in general use, and learning the opinions of the chemists employing them as to their special advantages and limits of error, at the same time collecting information on other closely related matters.

With the view of carrying out these intentions to the fullest possible extent, the Committee issued a circular letter setting forth its aims and objects, and sent it to every member of the Chemical Society, to all gentlemen known to be interested in the subject, and to such chemists as your Committee learnt would be likely to afford assistance.

The following is the letter referred to:—

"No. 1 Surrey Street,
Sheffield.
May 10, 1875.

"Sir,—At the last Meeting of the British Association, a Committee, consisting of Messrs. J. Dewar, A. Fletcher, E. C. Stanford, and myself as Secretary, was appointed, 'for the purpose of examining and reporting upon the Methods employed in the estimation of Potash and Phosphoric Acid in commercial products, and on the mode of stating the results.'

"The Committee proposes to ascertain, by inquiry, what methods are in general use, and to learn the opinions of the Chemists employing them as to their special advantages and limits of error, and also to collect information on other closely related matters.

"The Committee hopes to be enabled to recommend one or two accurate and practical processes for the estimation of Phosphoric Acid and Potash in commercial products which would meet with very general adoption by Chemists, and would be welcomed by both buyers and sellers as a perfectly neutral standard of reference. Such a plan, we believe, would do much to secure uniformity in such estimations and in the methods of stating the results.

"If you have experience in this description of analysis, you will much aid the Committee by filling up the accompanying paper, and returning it to me at your earliest convenience.

"A similar paper has been sent to all the Fellows of the Chemical Society; but if you know any other Chemists, whose advice and opinion would be of service to the Committee, we shall esteem it a favour if you will kindly send me their names.

"I have the honour to be,
"Your obedient Servant,
"ALFRED H. ALLEN,
Hon. Secretary of the Committee."

Together with the above circular letter, the Committee forwarded the following series of very carefully arranged questions, with the view of indicating the exact nature of the information they were in need of.

1. Will you give the Committee the details of the process you habitually employ for the estimation of the Phosphoric Acid in Commercial Phosphates?
2. What length of time does the above process require?
3. Are you of opinion that the method gives strictly accurate results? If not, will you state the direction in which the error occurs, and the maximum extent of it?
4. Would it be possible to eliminate the error by taking certain well-defined precautions?
5. Which process of analyzing Phosphates is in your opinion the most accurate? and how long does it require?
6. Which is the most rapid and convenient?
7. Which gives the most constant results in the hands of different manipulators?
8. Do you know of any reliable process for the estimation of the so-called "Reduced Phosphates?" If so, will you give details of the method?
9. Do you think it desirable that Chemists should be called on to state the commercial value of a manure?
10. What in your opinion are the relative values which should be attached to Phosphoric Acid existing in the following forms, taking free anhydrous Phosphoric Acid as 100?
    - A.—*As* Acid (soluble) Phosphate of Calcium.
    - B.—*As* insoluble Phosphate of Calcium.
    - C.—*As* "Reduced" Phosphate of Calcium.
    - D.—*As* Phosphate of Aluminium.
    - E.—*As* Phosphate of Iron.

11. If a native Phosphate containing oxides of Iron, Aluminium, and Calcium, and Phosphoric Acid has been acted on by Sulphuric Acid, in what forms do you suppose the Phosphoric Acid exists? and how would you state the analysis?

12. What means should be adopted to insure the samples submitted to Chemists for analysis fairly representing the composition of the bulk?

13. Will you give the Committee the details of the process which you consider the best for the estimation of Potassium in commercial Potash Salts? What are the limits of error in the process? Are accurate results obtainable by it in the hands of unpractised manipulators?

14. Which, in your opinion, is the correct mode of stating the analyses of Commercial Potash Salts, containing Soda and more than one Acid—*e. g.* commercial "Muriates," Sulphates, Nitrates, Carbonates, Potashes, and Pearl-ashes?

15. Can you give the Committee the name and address of any Chemist not a Fellow of the Chemical Society of London whose advice and opinion would be likely to be of service?

16. Write here your name and address, and please state qualifications or nature of any appointment.

No effort has been spared to make the objects of the Committee widely known, and nearly a thousand circulars have been distributed.

In the case of chemists known to have special knowledge of the subjects on which information was desired, the circulars were accompanied by manuscript letters from the Secretary requesting careful consideration of and full replies to the queries.

In answer to their request for information, the Committee has received contributions from a considerable number of chemists, both in England and on the Continent, the answers in many cases containing much original information, and being generally of the utmost value in enabling the Committee to form an opinion on the present state of the questions which it was appointed to consider and report on.

On receipt of the replies, a further correspondence was in many cases entered into by the Secretary, with the view of obtaining explanation of or further information upon doubtful points, and every means has been taken to elicit the views of correspondents.

The following is an alphabetically arranged list of chemists to whom the Committee is indebted for information:—

G. BERRAND, Ph.D. Manager of United Chemical Works of Leopoldshall.
CHAS. BLOXAM. Professor of Chemistry, King's College, London.
T. P. BLUNT, M.A. Chemist to Shropshire Chamber of Agriculture.

J. Campbell Brown, D.Sc. Professor at Infirmary School of Medicine, Liverpool, Public Analyst for Liverpool, &c.
Chas. F. Burnard, of Messrs. Burnard, Slack, & Alger.
Chas. A. Cameron, M.D. Analyst to Royal Agricultural Society of Ireland, Public Analyst for Dublin, &c.
Jn. Cammack. Analyst to Bridgewater Chemical Works, St. Helens.
A. H. Church, M.A. Professor at Royal Agricultural College, Cirencester.
W. M. Cowan. Public Analyst for Greenock.
John Cox. Chemist to Nottingham Mills Manure Company.
V. Cruse. Chemist to Messrs. E. Packard & Co., Ipswich.
Thomas Fairley. Analyst to the Yorkshire Agricultural Society, Public Analyst for Leeds.
W. Flight, D.Sc. Assistant Examiner in Chemistry, London University.
— Franz, Ph.D. Chief Manager, United Chemical Works, Leopoldshall.
C. R. Fresenius, Ph.D. &c. Wiesbaden.
W. Galbraith. Late Chemist to the Phospho-Guano Company, Liverpool.
W. A. Hamlet. Analyst to the Peruvian Government Guano Company Agency.
J. Hughes. Analyst to Lawes's Chemical Manure Company, London.
H. Joulie. Paris.
Alfred Kitchen. Whitehaven.
M. J. Lansdell, of Messrs. J. C. Nesbit, Lansdell, & Co., Analytical Chemists, London.
Sydney Lupton. The Harehills, near Leeds.
Leisler, Bock, & Co. Glasgow.
M. Lichtenstein. London.
Newton, Keates, & Co. St. Helens.
T. R. Ogilvie. Late Public Analyst for Greenock.
E. W. Parnell. Chemist at Desoto Alkali Works, Widnes.
J. Pattinson. Public Analyst for Newcastle-on-Tyne.
Manning Prentice, Jun. Stowmarket.
T. Reddrop. Chemist at L. & N. W. R. Co.'s Works, Crewe.
G. Rosenthal, Ph.D. Chemist to Messrs. Holloway Bros.
J. Ruffle. Late assistant to Dr. Voelcker, &c.
Alfred Sibson. Analytical Chemist, London.
G. L. Ulex, Ph.D. Hamburg.
Wallace, Tatlock, & Clark. Joint Public Analysts for City of Glasgow.
Robert Warington. Formerly chemist to J. B. Lawes & Co.
W. J. Williams. Chemist in charge of Phosphate Sewage Company's Works, Hertford.

It will be observed that in almost every case the replies have been from chemists having special experience in the analysis of commercial phosphates or potash salts; and their communications contain, in the aggregate, an amount of information on the subject probably far in excess of any previously collected.

With a few notable exceptions the Committee has received assistance from all the best known authorities on the subject; a few of the leading chemists known to have special experience of the kind required have not responded to the Committee's request for information, though their assistance was most courteously sought by a special letter in each case.

The cause of the silence observed in the above mentioned cases is probably similar to that which prompted the following reply from a well-known firm of chemists, whose results were in some degree the cause of the appointment of the Committee.

"*Mr. Alfred H. Allen.* "June 19, 1875.

"DEAR SIR,—We are in receipt of your favour relating to the examination of phosphates and potash salts; but we must decline to give you the information required, as we do not think ourselves called upon to publish our methods of analysis, which we have perfected after long and careful investigation, for the benefit of those who have not taken this trouble.

"We are, dear Sir,
"Yours obediently, &c."

A French chemist of very high standing says he belongs to that class of chemists who cannot afford to work "pour la gloire," but must keep their methods, their only capital, secret.

It is evident that the interests of science would materially suffer if a similar system were adopted by many chemists; but happily the above answers stand in striking contrast to the generous and elaborate replies that have in very many instances been sent to the Committee.

The answers received to the various specific questions put have shown in a very striking manner how very various and even irreconcilable are the opinions held by chemists on many of the points submitted for their consideration. On this account the Committee refrains for the present from expressing any definite opinions on the points in question; but feeling that the communications received contain much information which should be at once in the possession of those interested, it begs here to submit to the Association the following digest of the replies received up to the present time.

The Committee has avoided as far as possible any specific mention of the sources of the various items of information, but has departed from this rule in cases in which the value of the information would have been seriously diminished if the authority on which it was quoted had not been given.

PHOSPHORIC ACID.

Solution of the Manure and separation of Silica.

In the case of soluble phosphates treatment with cold water, with (in some cases) subsequent washing with hot water, seems universal. Most chemists prefer to take a considerable quantity of the manure, and grind it with small successive quantities of cold water in a mortar. An aliquot part of the filtered solution is taken for analysis.

With but one or two exceptions, hydrochloric acid is universally employed for effecting the solution of insoluble phosphates *.

In the great majority of cases they then recommend evaporation to complete dryness. Some operators omit this step as a rule, but classify it among the precautions necessary when great accuracy is required. The effect of evaporation to dryness is considered to be twofold; silica is rendered insoluble and fluorides are decomposed with volatilization of hydrofluoric acid or of fluoride of silicon. The residue is next treated with hydrochloric acid in the ordinary manner, and the insoluble silica filtered off †.

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* It is evident that the addition of a few drops of nitric acid is desirable here to insure the complete peroxidation of any ferrous compounds which may be present.

† It is evident that in presence of fluorides the silica here found will not strictly represent the quantity originally present in the sample.

Oxalic-Acid Method.

Of the chemists whose processes of analyzing phosphates have been communicated to the Committee, a decided majority precipitate the phosphoric acid as the double phosphate of magnesium and ammonium, after previously separating the calcium as oxalate.

Although there is no great difference in the general outline of the method followed, the most extraordinary variations occur in the details of the instructions, and in the precautions recommended to insure accuracy.

By far the greater number of chemists precipitate the calcium as oxalate after neutralization of the excess of acid. Some add citric acid previously to employing oxalate of ammonium. According to Mr. R. Warington this modification "occasions a deficiency of lime, oxalate of calcium being soluble in citrate of ammonium." Those chemists who add citric acid before precipitating the calcium usually employ an acetate to get rid of free mineral acid. Of course, the addition of citric acid then becomes a necessity when iron and aluminium are present, unless the precipitated phosphates of these metals are filtered off and estimated separately. This plan appears to have several advantages, and is recommended by some chemists of wide experience. By employing it, the phosphates of iron and aluminium (by most chemists believed to have a very limited manurial value) are separately estimated, and the subsequent addition of citric acid is rendered unnecessary and the iron introduced by its use avoided.

If the phosphates of iron and aluminium are not previously separated, the general plan is to neutralize the solution with ammonia till a slight turbidity ensues, to clarify the liquid by the addition of a few drops of oxalic acid, to add a moderate excess of ammonium oxalate, to heat the liquid nearly to boiling, and to filter off the precipitated oxalate of calcium. Some chemists filter again after cooling.

After careful washing of the precipitate, the filtrate is usually concentrated, a moderate quantity of citric acid added and then excess of ammonia. A precipitate may here occur of silica, fluoride of calcium, or oxalate of calcium. The more careful analysts leave the solution for a time to make sure that the liquid remains clear, or to filter from any precipitate.

Precipitation by Magnesia.

The clear solution is next precipitated by "magnesia mixture," which is universally admitted to be better made with chloride than with sulphate of magnesium. It is also clearly proved and generally recognized that a large excess of the precipitant should be avoided, some chemists recommending a preliminary analysis of the sample with the view of adding the approximately theoretical quantity of solution. On the other hand, it has been proved that complete precipitation is very slow except in presence of a considerable excess of "magnesia mixture."

Very great variation occurs with respect to the concentration and temperature of the solution at the time of precipitation. A few chemists recommend precipitation in a hot solution, but the majority direct precipitation in the cold; one or two recommend the use of a dilute solution, while others concentrate, if necessary, to a certain bulk; and some make a correction for the solubility of the double phosphate in the liquid.

The amount of free ammonia present during the precipitation varies from a moderate excess to one fifth of its bulk of the strongest ammonia (·880).

The time allowed for precipitation varies from ten minutes (with vigorous stirring) to twenty-four hours; but most chemists are of opinion that six or eight hours are sufficient.

Very few chemists recommend re-solution and re-precipitation of the double phosphate.

But few precautions appear to be taken in the ignition of the precipitate. The more careful analysts thoroughly dry the precipitate and remove it from the filter, igniting it first gently, then intensely.

Very different opinions are held as to the accuracy of the results obtained by precipitation with magnesia. In many cases the observers are merely able to say that the process gives fairly constant results on repetition; in other cases they state that very concordant results have been obtained when the same sample has also been analyzed by some chemist of repute.

In some cases the observers consider that the process is liable to give results somewhat below the truth, owing to the slight solubility of the double phosphate in the mother-liquid and the loss of phosphate in the oxalate-of-calcium precipitate. In other cases the process is said to give results in excess of the real amount, owing to the presence of other magnesium salts or of iron or aluminium in the double phosphate precipitate.

A most elaborate series of experiments has been made by Mr. T. R. Ogilvie on the magnesia process and the variations to which it is liable*. His results have been to a great extent confirmed by the researches of Mr. E. M. Dixon. On the other hand, Professor Church writes, "My confidence in this plan when carried out successfully, giving time for any oxalate to fall after addition of citric acid and excess of ammonia, is not shaken by Ogilvie's results reported recently in the 'Chemical News.' His experiments seem to me to exaggerate the errors of the method greatly. Several times have I got nearly identical results by the use of the molybdic method for separating the P_2O_5 from the soluble part of a superphosphate, and by the use of the oxalic method. I always use a measured quantity of the ammoniacal magnesium chloride; but considerable excess of this reagent often produces but little influence on the result—sometimes none."

Direct Citric-Acid Method.

The method of Joulie is employed by some chemists of wide experience. In this process the iron, aluminium, and calcium are all retained in solution by citrate of ammonium, and no attempt is made to separate the calcium as oxalate; but the phosphate is at once precipitated from the ammoniacal solution by "magnesia mixture," the precipitate being either ignited and weighed or dissolved in acetic or nitric acid and the solution titrated with uranium. This method is in many respects similar to that recommended by Fresenius, Neubauer, and Luck †.

Iron-Acetate Method.

A few chemists employ a process of which the following is an outline:—

The neutralized hydrochloric solution of an insoluble phosphate (freed from silica), or the aqueous solution of a soluble phosphate, is treated with acetate of ammonium (filtered from the precipitated phosphates of iron and aluminium if their separate estimation is required) and sufficient ferric chloride added to cause the precipitate to appear distinctly reddish. The liquid is boiled, well filtered, and the precipitate washed slightly. It is redissolved on the filter in hydrochloric acid, tartaric or citric acid added judiciously to the solution, and then a tolerable excess of ammonia. The alkaline solution should be greenish, not reddish. "Magnesia mixture" is then added in moderate excess, the liquid stirred and left over night. The precipitated double phosphate is then filtered off and treated in the ordinary manner. The method gives results agreeing well with the average of chemists of repute. On repetition, the results of the two estimations agree within ·1 to ·2 per cent.

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* Chemical News, May 6, 1870; Proceedings of the Philosophical Society (Chemical Section) of Glasgow, 1874 and 1875, &c.

† Zeit. f. anal. Chem. ix. 16, and Sutton's 'Volumetric Analysis,' second edition, p. 241.

Phosphates of Iron and Aluminium.

The precipitate of iron and aluminium phosphates, produced by treating the cold solution of a sample containing the above metals with an alkaline acetate (or with ammonia and excess of acetic acid), can be very conveniently analyzed by the following method, contributed by Mr. R. Warington:—"The precipitated phosphates of iron and aluminium are washed, ignited, and weighed, redissolved in strong hydrochloric acid, and the iron determined volumetrically with stannous chloride and iodine (see Fresenius). From the iron the quantity of ferric phosphate in the precipitate is calculated, the phosphate of aluminium found by difference, and thus the iron, aluminium, and phosphoric acid in the precipitate are obtained. A littl phosphoric acid is liable to be removed from the precipitate during washing and basic salts are thus reckoned in the calculation as of normal composition."

Estimation by Uranium.

The removal of iron and aluminium by addition of an alkaline acetate in the cold, with determination of the phosphoric acid in the filtrate by mean of uranium *, is a method which appears to deserve more extended employment. The use of an acetate in a slightly acid solution brings the liqui into just the condition required for the use of the uranium process. Th volumetric estimation by uranium is very highly spoken of by some chemist as convenient and fairly accurate, while others consider it very unsatisfactory The conflict of opinion is very great, and special experiments on this proces appear desirable; but the following seem to be the precautions necessary fo successful working.

The proportions of acetic acid and alkaline acetate employed and th volume of the solution should be approximately constant. The uranium nitrate should be standardized with an acetic-acid solution of pure precipitated ammonio-magnesium phosphate or tricalcic phosphate, instead of wit phosphate of sodium as is commonly done.

The titration should be *converse*, the solution of the phosphate being adde to that of the uranium. The latter should be mixed with a constan proportion of acetic acid and heated on a bath of boiling water. Th indicator should be powdered potassium ferrocyanide on a white plat Owing to the reversal of the usual process, the brown colour of the ferrocyanide of uranium becomes gradually fainter till the end of the titration.

This method, which is recommended and employed by some authorities o great experience, is said to be capable of giving results of every desirabl accuracy.

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* It is universally admitted that the estimation by uranium is untrustworthy unle any iron or aluminium present in the original solution is first removed.

The gravimetric method of precipitation by nitrate of uranium is employed by a few chemists, and is very well spoken of.

Molybdic-Acid Method.

Of all methods, Sonnenschein's process of precipitation with molybdic acid appears to be regarded as the most accurate. All the chemists who refer to it speak of it as extremely accurate, and consider that it is preferable to any other in presence of much iron or aluminium; but comparatively few use it habitually. The causes of this unpopularity are the time required and the expensive nature of the reagent.

As a very large excess of molybdic acid is required above that which is actually precipitated as "phospho-molybdate of ammonium," it becomes an important matter to recover the molybdic acid from the solution. Unfortunately no very simple process of effecting this appears to have been devised.

The yellow precipitate obtained, containing as it does less than four per cent. of anhydrous phosphoric acid, becomes very bulky and unmanageable when the weight of phosphoric acid present exceeds ·1 or ·2 gramme. This fact necessitates the employment of very small quantities of the phosphate; and as the yellow precipitate has to be subsequently redissolved and precipitated with magnesia mixture in the ordinary way, the error liable to occur from the use of an unusually small weight of the sample, together with the loss of time and expense incident to the use of the process, seem to have combined to render the method unpopular for every-day work *, while its value is generally admitted when the above considerations are of secondary importance.

J. Macagno has very recently proposed to reduce the yellow precipitate with zinc and acid, and titrate the solution so obtained with standard permanganate. The test experiments show a maximum error of ·5 per cent. of the phosphoric acid present.

Eggertz's Molybdic-Acid Method.

Metallurgial chemists are well aware that M. Eggertz has proposed to weigh the yellow precipitate of phospho-molybdate of ammonium instead of redissolving it and converting it into ammonio-phosphate of magnesium in the ordinary manner.

The modified plan has the advantage of speed; and the fact that the precipitate contains less than four per cent. of phosphoric anhydride would render the results extremely accurate.

Unfortunately it seems improbable that the precipitate has a constant composition; and any sensible variation in the proportion of phosphoric acid contained in it would render it worthless as a method of estimation, at least as far as manures are concerned.

M. Eggertz estimates the anhydrous phosphoric acid contained in the yellow precipitate, obtained under the conditions prescribed by him, at 3·72 per cent.

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* Mr. A. Sibson writes:—"The molybdic-acid process is, in my opinion, not suitable for phosphatic minerals, although invaluable for soils, limestones, &c. containing small proportions only of phosphoric acid. The large excess of molybdic acid necessarily employed in the former case is itself a source of error with no adequate advantage, inasmuch as the magnesia precipitate has still to be employed; and it is in the manipulation of this precipitate that the differences in analyses chiefly arise."

Other Methods.

Besides the above-described processes, and trifling modifications of them, descriptions have been received of no other method. The lead, bismuth, and tin processes appear to have fallen into complete disuse. No chemist has reported that he precipitates phosphoric acid as tricalcic phosphate by direct addition of ammonia to the original solution.

"Reduced" Phosphates.

Of all the chemists who have communicated with the Committee, only two consider that the so-called "reduced" phosphates can be estimated even approximately by any known method.

One of these writes as follows:—

"I employ a process based on the ready decomposition of gelatinous phosphate of lime by oxalate of ammonia [*], and the almost complete inaction on the mineral phosphate by the same salt. Although not an exact process, it gives good approximate results within ½ per cent.; and seeing the urgent need for some such means of estimation, more especially in the case of bone-manures, in which a large proportion of decomposed phosphate may exist unrecognizable by the ordinary soluble phosphate determination, I think it better to employ even an imperfect process than to classify such decomposed phosphate with undecomposed mineral phosphate."

Professor A. H. Church, referring to the bicarbonate-of-sodium method described in his 'Laboratory Guide'[†], writes, "It is the only method giving approximate results."

A series of highly instructive experiments on the estimation of "reduced" phosphates has been contributed by Mr. M. J. Lansdell.

With the oxalate-of-ammonium method of Mr. Alfred Sibson [‡], and with the bicarbonate method (which was first described by Mr. Chesshire [§]), Mr. Lansdell obtained the following results, the samples being all passed through the same sieve and the proportions employed being the same as those recommended by the authors.

	Sample contained (equal to $Ca_3P_2O_8$).	Dissolved (equal to $Ca_3P_2O_8$). By Sibson's method.	By Chesshire's method.
Cambridge coprolite	56·07 per cent.	8·32,	2·23 per cent.
Bone-ash	76·87 ,,	10·58,	3·07 ,,
Navassa phosphate	65·62 ,,	7·48,	5·73 ,,
German phosphate	60·74 ,,	8·04,	2·09 ,,
Redonda phosphate (dried)	87·42 ,,	19·72,	56·97 ,,
Redonda phosphate (lump)	86·58 ,,	19·10,	64·65 ,,

By employing a solution of bicarbonate of twice the above strength, the Redonda phosphate gave equal to 84·3 of $Ca_3P_2O_8$ in solution.

Using a smaller quantity of the sample in the oxalate method, 47·76 per cent. passed into solution.

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[*] See Chem. News, Sept. 10, 1869, p. 123.

[†] 3rd Edition, p. 146. This process consists in boiling the insoluble portion of 5 grammes of the sample for one hour with a solution of 10 grammes of sodium bicarbonate in 300 cub. centims. of water; filtering hot, acidifying, concentrating, precipitating with magnesia, &c.

[‡] Chem. News, Sept. 10, 1869.

[§] *Ibid.* Sept. 3, 1869, p. 111.

The above results show that neither method is at all satisfactory; and Mr. John Hughes[*] has made experiments leading to the same conclusion.

Another correspondent writes, "There is no reliable process known for the estimation of 'reduced phosphates' under all circumstances. Even the citrate-of-ammonium method (which seems to be the one generally preferred) utterly fails to distinguish between 'reduced phosphate' and the native phosphate of aluminium known as 'Redonda phosphate,' the latter being largely soluble in the citrate-of-ammonium solution; so that the latter, which is a comparatively cheap material, if introduced into a superphosphate, would, according to the results obtained by the methods usually employed for estimating reduced phosphates, be quoted as the latter."

Mr. T. L. Patterson has criticised the citrate-of-ammonium method in a paper contributed to the 'Chemical News'[†].

Mr. W. Galbraith makes the following remarks on the estimation of "reduced phosphate":—

"It seems to me that an arbitrary method of determining these phosphates would serve every purpose—that is, provided there is a necessity for determining them (from a commercial point of view), which I am inclined to dispute; because any other phosphate in as fine a state of division as these 'reduced phosphates' is of equal value; and if (as some chemists maintain) these 'reduced phosphates' consist principally of phosphates of iron and aluminium, they cannot and should not be reported as, or assumed to be, phosphate of calcium.

"It is well known that the presence of oxide of iron and aluminium is the cause of the manure 'going back.' Superphosphates containing no iron and aluminium do not 'go back;' so that the manufacturer has the remedy in his own hands—to avoid using mineral phosphate containing iron and aluminium.

"At present a manufacturer who makes his manure from a phosphate containing iron and aluminium, and who sells it immediately after manufacture, has a decided advantage over another manufacturer who has made his manure from a phosphate containing no iron and aluminium, because a mineral phosphate containing iron and aluminium is much cheaper than one free from those substances. Besides, the iron and aluminium are almost invariably stated in the analysis of a mineral phosphate, while those substances are seldom if ever mentioned in the analysis of a superphosphate.

"I do not think it advisable (even if possible) to determine the *actual* amount of 'reduced phosphates;' but an arbitrary method, or a method of determining phosphates of a given fineness, which would include 'precipitated phosphates,' would, I think, be very serviceable; and such a process could be easily devised."

Statement of the Commercial and Agricultural Value of Manures.

Without exception, all the chemists who reply to this question are of opinion that it is highly undesirable that analysts should express any opinion on the commercial value of a manure. Many of them believe that tricalcic phosphate (for instance) has a very different value according to its origin and state of division, and that any valuation of a manure not taking this and similar facts into account must be worse than useless. Most of the chemists who have replied consider that phosphates of iron and aluminium have an exceedingly limited manurial value. The *relative* manurial values attributed to phosphoric acid existent in various states is very differently regarded; and as many of the opinions expressed appear to be based on very insufficient evidence, the Committee thinks it unnecessary to quote the different replies received.

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[*] Chem. News, June 4, 1869, p. 266.

[†] May 31 and June 7, 1872.

Mode of occurrence of the Constituents of Manufactured Manures, and statement of the Results of Analysis.

On this subject the Committee has received a large amount of valuable but somewhat discordant evidence.

Very strong opinions are expressed to the effect that the quantity of iron and aluminium present in a manufactured manure (superphosphate) should always be stated. Such a plan would enable the manufacturer or purchaser to judge of the probability of a newly made manure "going back" on keeping, and would enable a more accurate opinion to be formed of its true value than is possible while the presence of iron and aluminium is ignored. At the same time the estimation of the "reduced phosphates" would often be rendered superfluous.

With respect to the mode of occurrence of the constituents of manufactured manures, the Committee considers the evidence before it too vague and conflicting to justify any expression of opinion at present.

POTASH SALTS.

Estimation of Potash.

The Committee has received comparatively few replies on the estimation of potash in commercial salts containing it, on account of the limited number of chemists having special experience in its determination. The answers received are, however, from chemists of the first rank as authorities on the subject, and appear to be almost exhaustive of the question.

The method of estimation by platinic chloride is employed by all the chemists who have communicated their processes to the Committee, the only differences being in the manipulation and details of the method.

Some chemists recommend the removal of any sulphates by addition of a slight excess of chloride of barium, and some also remove any calcium or magnesium which may be present.

The Committee is in possession of some correspondence respecting a sample of "muriate" which was analyzed independently by Professor Fresenius and Mr. R. R. Tatlock; and as it throws much light on the origin of the discrepancies often observed in the estimation of potassium, the Committee quotes it almost *in extenso*, together with a description of the methods employed by the two authorities above referred to.

Messrs. Wallace, Tatlock, and Clark write:—

"We employ the platinic-chloride method as described by Fresenius in the sixth edition of his 'Quantitative Analysis,' with a slight modification which renders it more applicable to all the numerous varieties as well as strengths of commercial potash salts. After pounding and mixing in the usual way, a quantity of the salt (500 grains) is weighed out, dissolved in hot water and filtered. The filtrate and washings being cooled to normal temperature are mixed well, made up with cold water to a fixed bulk (5000 grains) and again mixed; a portion of this solution (100 grains), equal to 10 grains of the original sample, is delivered into a small basin, diluted with 400 grms. or so of water, and acidified slightly with hydrochloric acid.

"About 500 grains of platinic-chloride solution (containing at least 25 grains of platinum) are added, and the fluid evaporated nearly to dryness on the water-bath. A few drops of water are then added to the residue, and the evaporation repeated to expel the excess of hydrochloric acid. About 50 grains more of the strong platinic solution are mixed with the precipitate, and the whole stirred well and set aside in a cold place for at least an hour with occasional stirring. The precipitate is then thrown on a very small filter (unweighed), the basin rinsed out with about 10 drops more of the platinic solution, and the precipitate on the filter washed with 10 or 15 drops more. The basin with the filter and contents are then washed with the smallest possible quantity of alcohol of 95 per cent. strength, and dried at 100° C. The dried precipitate is transferred as completely as possible to a small capsule, in which it is further dried until it assumes a distinct orange-colour, and weighed. The filter and trace of adhering precipitate is ignited on a crucible lid, and the residual metal with its corresponding chloride of potassium calculated to potassio-platinic chloride, and the weight added to that of the precipitate. The following factors are employed:—To bring the precipitate to potassium ·1603, to potash ·1930, and to chloride of potassium ·3056. The figures are based on Stas's numbers for potassium and chlorine, and Berzelius's equivalent for potassium."

Professor Fresenius writes:—

"I am quite ready to go once more closely into the question regarding the estimation of potassium in commercial potash salts. However, I can only do so occasionally when I am at leisure, for there are a great many experiments still to be made before being able to give a satisfactory answer. As far as I am concerned myself, as well as the analyses in my laboratory, these questions are of no great importance. The great object I have in view is to be accurate; saving time is only a secondary consideration. I begin by entirely separating from the solution the sulphuric acid, lime, and magnesia; then I weigh the pure chloride of the alkali-metals, estimate the potassium as platino-chloride of potassium according to the method given in my manual of quantitative analysis, make sure that it is quite pure, and generally also estimate the chloride of sodium in the washings by evaporating and heating the residue in a current of hydrogen*, partly to have a check, principally, however, to make sure that it contains no more potassium. This method, however, is not practicable in works because it is too elaborate."

In reference to the estimation of potash, Messrs. Wallace, Tatlock, and Clark also write:—

"It is a notorious fact that while the results obtained by the process we follow, as compared with those got by what we may term the alcohol method, agree very closely in the case of *potassium compounds free from sodium*, wide differences have been observed when the potassium salts were of low strength from the presence of sodium compounds. To this fact it would not be difficult to get manufacturers and merchants to testify. This remark applies specially to the case of potassium products from kelp, of which many thousand tons are made in Glasgow every year, some of which contain a large proportion of sodium sulphate, which is not readily convertible into sodio-platinic chloride, but must be converted into chloride by double decomposition with barium chloride—a tedious and unnecessary process, and one liable to lead to error in any than very skilled hands.

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* How the proportion of chloride of sodium present is deduced from the weight of the ignited residue is not stated. Probably by washing with water and subtracting the weight of the residual metallic platinum.

"Sulphate of potash made from kelp is an excellent example of the kind of salt, as it usually contains about 20 per cent. of sodium sulphate in the form of the double salt $3K_2SO_4+Na_2SO_4$.

"It was with the view of obtaining a process for the estimation of potassium by platinic chloride, directly, in these compounds, that the process we employ was originated, and it has stood the test of practice for 15 years. It has been objected to our process that the potassio-platinic chloride is soluble to an appreciable extent in platinic-chloride solution; but our experience goes to show that in the circumstances of a potassium determination, as above described, the results obtained are accurate. As an instance of this, we may mention that a German firm, supposing that we must necessarily get too high results, handed to us for analysis, in the usual commercial way, a sample of muriate of potash. We found and reported, as the result of the only trial made, 99·95 per cent. of chloride of potassium, and were afterwards informed that the sample consisted of pure chloride of potassium, prepared and sent in order to test our process. A further instance will suffice to show the exactness of this mode of estimating potassium in presence of sodium compounds in quantity. A portion of a carefully mixed and pounded sample of muriate of potash, of which we had made previously a complete analysis as usual by this method, was forwarded by our client to Dr. Fresenius, unknown to us, with the request that he would spare no pains to arrive at the truth regarding the relative proportion of potassium and sodium salts which it contained. The following are the results of the respective analyses:—

	W. T. & C. per cent.	Fresenius. per cent.
Chloride of potassium	88·50	88·86
Sulphate of potash	·13	..
Chloride of sodium	8·46	8·39
Sulphate of lime	·18	·22
Chloride of magnesium	·50	·47
Insoluble	·23	·23
Water	1·80	1·83
	99·80	100·00
Potash	55·97	56·10
Equal to chloride of potassium	88·65	88·86"

With reference to Mr. Tatlock's method and the above analyses, Dr. Fresenius writes:—

"I must object to his washing the precipitate with chloride of platinum. He dissolves by doing so a small quantity of chloride of platinum and potassium; and you see that he makes the chloride of potassium 0·21 per cent. lower than I. This discrepancy, however, will scarcely ever be greater. To make sure not to keep any chloride of sodium along with the chloride of platinum and potassium, I first extract the chloride of platinum and sodium with spirits of wine of 80 degrees, and then wash the chloride of platinum and potassium with a few cubic centimetres of water drop by drop; then I evaporate this solution, adding a little chloride of platinum, treat the small precipitate again with spirits of wine, and add the small quantity of chloride of platinum and potassium to the bulk."

In reply to the above criticism the Glasgow chemists say:—"In his analysis of this sample Dr. Fresenius followed the method described in the sixth edition of his 'Quantitative Analysis;' but, evidently fearing that the digestion of the precipitate with alcohol of even 80 per cent. might not free it from sodium compounds, he used a little water, wherewith to ensure the separation of the latter, and afterwards estimated the potassium in the washings obtained, adding this to the main result:—a plan which of course can be equally adopted with our process if considered necessary"*.

Messrs. Wallace, Tatlock, and Clark further write:—

"Our method obviates the necessity of converting sulphates into chlorides before applying the platinum process. All that is necessary in the case of these salts, or where they are present, is to add an equivalent quantity or rather more of pure sodium chloride, which takes up the liberated sulphuric acid. We believe that the general tendency is to report potassium results too high, not only on account of incomplete removal of sodium compounds from the potassium precipitate, but by reason of impure platinic solutions, which, however pure when originally made from the metal, are liable to contamination through the spent liquors and precipitates being recovered by questionable means.

"There is almost no limit to the accuracy of this process; with care and in good hands, the potash may be estimated easily to within ·05 per cent."

Mr. W. Galbraith, who has had great experience in the analysis of potash salts by Mr. Tatlock's method, writes of it as follows:—

"The method requires a few precautions, the principal of which are that the pipette be accurate and that the platinic chloride be pure. Care also should be taken that the evaporation should not go to dryness, especially in presence of a large quantity of soda salts, or the result will be too high. By diluting the solution previous to the evaporation, the precipitate comes down in larger crystals, is more easily filtered and taken off the filter, and is also more likely to be pure.

"With these precautions, which are easily attended to, the method gives rigidly accurate results even in the hands of inexperienced manipulators."

Dr. G. L. Ulex, of Hamburg, separates any sulphates by very cautious addition of chloride of barium. He washes the chloroplatinate of potassium with alcohol of 80 per cent. He obtains results reliable within ·2 per cent. The process, "although simple, requires to be worked carefully, otherwise serious mistakes will be made."

Mr. M. J. Lansdell says, "I consider the great secret is to use plenty of platinum, which facilitates the washing out of the sodium salts, and renders the indication by colour (as to when to arrest washing) distinct."

M. Joulie separates sulphates, and then the barium introduced, together with any calcium or magnesium present. He washes the chloroplatinate with a mixture of alcohol and ether. Absolutely exact results are obtained in 5 or 6 hours, whatever the nature of the original sample.

Dr. G. Berrand uses a large excess of platinic chloride, and washes the precipitate with alcohol of 98 per cent. He removes any sulphates with a slight excess of chloride of barium. He remarks that "the most essential point of the whole method is the purity of the chloride of platinum, which can be well proved by testing it with chemically pure muriate of potash. This, of course, must yield 100 per cent. If more or less, the platinum solution has not been pure. If the platinum solution is correct, even less practised hands will obtain exact results by the above method, which is now universally applied in the manufactories of our place."

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* As the quantity of platinic-chloride solution employed by Mr. Tatlock for washing the precipitate does not exceed 70 fluid grains, the solution of any sensible quantity of the latter seems improbable, and if occurring might be altogether prevented by previously saturating the platinic chloride used for washing with the potassium salt.

The above replies and correspondence show conclusively the necessity for independent experiments on *mixtures* containing known amounts of real potash.

Statement of Results of Analyses of Potash Salts.

The information the Committee has received on this subject is limited to the opinions of a few chemists. Without endorsing the whole of the following observations, the Committee believe that the subjoined remarks will be read with interest and advantage.

"It is quite likely that the sulphuric acid exists in these (kelp) muriates not as sulphate of potash, but as the double salt $3K_2SO_4+Na_2SO_4$ (discovered in kelp potash salts by Penny of Glasgow); and if so, the large proportion of sulphates present in kelp muriates (usually from 4 to 6 per cent.) would involve a slight alteration in the mode of stating the results, and would introduce sodium sulphates to a small extent. This view, however, even if proceeded upon in practice, would not interfere practically with the commercial value of the sulphates.

"There cannot be a doubt that the alkali present is carbonate of soda, both from the fact of these muriates *not being deliquescent*, and the impossibility of the existence of carbonate of potash and chloride of sodium together without mutual decomposition; otherwise carbonate of potash could be made by the simple process of mixing solutions of carbonate of soda and chloride of potassium."

Dr. Ulex, of Hamburg, writes:—

"Potash, carbonate of potash, and pearlash generally contain sulphates (which require to be removed carefully by a chloride-of-barium solution before estimating the potassium). The whole of the potassium is estimated as chloride of platinum and potassium, and calculated to oxide of potassium. The sulphuric acid present is precipitated with chloride of barium as sulphate of baryta, the chlorine with a solution of silver as chloride of silver; the former is calculated to sulphate of potash, the chlorine to chloride of potassium. The oxide of potassium equivalent to these two salts is subtracted from the total oxide of potassium, and the remainder calculated to carbonate of potash. Part of the sample is titrated with sulphuric acid and noted as carbonate of potassium. Subtract from this the carbonate of potash previously found and calculate the difference to carbonate of soda."

Mr. W. Galbraith writes as follows:—

"Muriates, which may be alkaline and contain sodium carbonate, and therefore will not contain calcium or magnesium soluble in water, I should state thus, putting the stronger bases and salt-radicals first:—

Potassium.	Sulphate.
	Chloride.
Sodium.	Carbonate.

"When they contain calcium and magnesium soluble in water, they should be stated thus:—

Calcium.	Sulphate.
Potassium.	
Magnesium.	Chloride.
Sodium.	

"In the case of 'artificial sulphates,' which contain iron, calcium, and magnesium, in addition to potassium and sodium, and are usually acid, the results may be stated thus:—

Hydrogen.	
Calcium.	Sulphate.
Potassium.	
Iron.	Chloride.
Magnesium.	
Sodium.	

"The free acid I should state as sulphuric acid, as I cannot believe that it exists as hydrochloric acid, considering the heat of the furnace during the manufacture.

"Of course it is evident that the acidity will not be really due to *free* sulphuric acid, but to an acid sulphate, probably acid sulphate of potassium ($KHSO_4$). Lumps of chlorides are often to be found in salt cakes and potassium sulphates of decided acid reaction.

"Of course carbonates should follow the same rules as the above."

Mr. M. J. Lansdell holds the following opinions:—

"I think in this, as in all other instances, it is a mistake to give detailed analyses showing any particular arrangement of acids and bases combined. I advocate a simple statement of the elements (or acids and bases) separately, and any combining of them I am inclined to look upon as padding only (to use an expressive word), and as having weight only with the uninitiated. I do not object to a statement of any one substance (say a base) as being *equal* to a salt, not in the sense that that amount of that salt is *present* in that sample, but as a trade valuation of the base (present) according to a well-known or usual standard for its valuation. I find the practice of latter years among our clients is to ask only for certain determinations (in potash salts, generally of potash only, or for potash and its equivalent amount of sulphate of potash or chloride of potassium), and not for detailed analyses, so getting them done at a less fee. However, I should see no objection if the Committee thought fit to prescribe a mode of statement for detailed analyses which they found suited to the requirements of the trade, it being understood that such analysis, quoted perhaps as the 'B. A. statement' or 'B. A. analysis,' was only a statement in a conventional form. Yet a statement of the elements (or acids and bases) determined—with at most their amounts in equivalent proportions (each equivalent proportion =1 of hydrogen)—would give to each manufacturer an easy means of making all calculations useful to him as to value or the capabilities of the articles for separation or manufacture thereof of any compound, and would not parade a lot of fictitious or supposititious information to impose upon or awe the ignorant. I incline to the belief that every analyst should have respect to the ends sought and need not go beyond them. A trader, only finding some constituent or constituents of value for his purpose, should be accommodated with estimations of such on paying properly for them, and should not be led to require as 'the thing' a lot of other information involving greater trouble and higher fees to the limitation of general reference to the chemist. The sooner the public learns that chemists do not want to take advantage of them, but only to do what is of use to them, and that fees are not to be regulated by the *number* of items given (any more than an amount of money by the number of coins of various values it may be paid in, but also by the intrinsic value of each), the better I think it will be."

In the foregoing Report the Committee has attempted to give an epitome of the very voluminous replies which have been received.

It will be perceived that there are many points on which the evidence is very conflicting; and the Committee feels it impossible to recommend with confidence any particular process or processes unless the special conditions of accuracy are very clearly defined.

The large amount of information amassed during the past year has indicated very distinctly the directions in which further research is desirable; and the Committee, if reappointed, will be able to complete the proposed experiments and inquiries before the next Meeting of the Association, and make a full report on the whole subject it was appointed to investigate.

Report on the Present State of our Knowledge of the Crustacea.— Part I. *On the Homologies of the Dermal Skeleton. By* C. SPENCE BATE, *F.R.S. &c.*

[PLATES I. & II.]

IN presenting a Report on the present state of our knowledge of the Crustacea, I do not think that I should fulfil the object in view without drawing attention to what must be one of the greatest hindrances to the progress of any study in an exact or scientific manner. I allude to the want of a uniformity in scientific nomenclature.

The names of the several groups and families, as well as those of the structure of the animals, given by the earliest carcinologists, having been based on a limited knowledge both of the forms and the variation to which this great subkingdom is liable, make them inapplicable to the knowledge of the period. Leach named one great group of Crustacea *Decapoda*, from the number of legs that it possesses; and Dana more recently named another group *Tetradecapoda*, from the fourteen legs that belongs to its most normal forms.

Observation has demonstrated that in this latter group some genera, as *Anceus*, have but eight legs; while in the Decapoda it is only a conventional rule that prevents the genus *Palæmon* and its allies from having the appendages of the percion anterior to the last five pairs counted as legs.

But a greater difficulty still exists where the names given to any parts of the animal carry any significance with them that precludes their being accepted in their universally correct sense. Thus the third pair of maxillipedes in the Brachyurous Crustacea are identical with the first pair of walking-legs in the Stomapoda, Amphipoda, and most of the Isopoda.

It is now exactly twenty years (1855) since I presented to the Association a Report on the British Edriophthalmia, in which the same difficulty was pointed out and a nomenclature suggested which, it was hoped, would to a large extent overcome the great difficulty in the study of this branch of natural history.

But although many of the terms there given have become very general in use, yet the custom of some writers of applying different ones at separate times for the same parts is significant of a confusion of ideas that precludes the student from a just appreciation of the labours of others.

I do not think that this difficulty will be overcome for some long period unless a committee is appointed by this Association, consisting of all the best known authors of carcinological works, who shall determine upon a systematic nomenclature for the structure and classification of the Crustacea to which all future writers shall conform.

In this Report I purpose provisionally, except when quoting from others, to make use of the same terminology as that adopted in the previous Report, and confine each term to that which has homologically the same signification.

In the classification of Crustacea in his great work*, Dana states that "in the crustacean type there are normally twenty-one segments, and correspondingly twenty-one pairs of members, as laid down by Milne-Edwards, the last seven of which pertain to the abdomen (pleon) and the first fourteen to the cephalothorax (cephalon and pereion). Now we may gather from an examination of the crab, or macrural decapod, acknowledged to be first in rank, what condition of the system is connected with the highest centralization in Crustacea.

"In these highest species, *nine* segments and nine pairs of appendages out of the fourteen *cephalothoracic* belong to the senses and mouth, and five pairs are for locomotion. Of these *nine*, three are organs of senses, six are mandibles and maxillæ."

M. Milne-Edwards, in his standard work 'Histoire Naturelle des Crustacés,' says, "We can generally distinguish among these animals a head, a thorax, and an abdomen; but the limit of these regions is not always naturally well defined; and it is not well to attach too much importance to these distinctions, for they do not correspond with the same parts among mammals, birds, &c. . . . ." And in a note to the above he says, "Guided by the principal viscera some authors have given the name of abdomen to the thorax, and that of postabdomen to that which we call abdomen; but after this principle we must consider the head to be a preabdomen, because it contains the same viscera as the thorax and abdomen."

The twenty-one somites of the typical Crustacea M. Milne-Edwards has thus divided—the anterior seven to the head, the next seven to the thorax, and the posterior seven to the abdomen. But in his nomenclature of the appendages the terms used are suggestive of the anterior two pairs of the thorax being attached to the head. In his "Observations sur le Squelette tégumentaire des Crustacés décapodes," Ann. des Sciences, 1854, the same author states that "he has often been convinced that in many branches of zoology the difficulties of the study are considerably augmented by the imperfection of the language by which we attempt to formulate the results of our observations. The employment of expressions that are vague in the determination of zoological characters and the description of the parts that constitute an organism convey naturally the superficial observation with which the observer was content, leaving in the mind of the reader an amount of doubt which retards his desire for distinct information . . . . . . The terms," he continues, "of zoology are far, at present, from that degree of precision . . . . . These considerations have determined me to make a general revision of the

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* United States' Exploring Expedition, p. 1397.

'carcinological terminology' before presenting to zoologists the work that has engaged me for some time on the natural distribution of Crustacea from the collection in the natural-history museum."

Even after this M. Milne-Edwards uses the terms head, thorax, and abdomen, which he had previously stated to be "regions not naturally defined," and gives the appellation of *pemptognathe* and *hectognathe* to the first and second pair of appendages attached to the thorax (or pereion). Dana made his researches on the highest form in crustacean life; so also has M. Milne-Edwards in his later observations. But the two appendages which this latter author determines as the seventh and eighth pairs of gnathes are invariably, according to his own showing, the anterior two pairs of the thorax. It is only in the highest and most consolidated form of crustacean life that we find them variated from their typical character so as to make them appear organs attached to the mouth; whereas in a very considerable proportion of the various forms of Crustacea they never act as attendants on the mouth, but are simply prehensile in their character or locomotive in their power: but almost universally throughout Crustacea they are connected with a pair of branchial appendages; and in this they fulfil most efficient work, so that in the highest types their connexion with the mouth is one of secondary importance only.

The first two pairs of appendages belonging to the pereion (or thorax), through nearly all the orders, of the typical crustacean exhibit a variation that distinguishes them from those posterior to them; and it may be convenient to define them, but certainly not by a term that confuses them with appendages that are only connected with secondary duties.

Taking into consideration the many and various forms of Crustacea, the great and numerous changes they undergo, it is desirable not only to be sure that the nomenclature shall be scientifically correct in its determination and homological signification, but that it is convenient and applicable to a very considerable proportion of the animals it has to define.

A typical crustacean in any of the well-defined orders can readily be divided into three parts, each part to consist of seven somites.

The *first division* we call the CEPHALON*. It consists of the anterior seven somites, and supports the organs of sense and appendages adapted to be attendants on the mouth.

The *second division* we call the PEREION. The seven somites that form this division support appendages that are more or less adapted for walking in their most normal condition.

The *third division* we name the PLEON. This consists of the posterior seven somites; these support the appendages which, when developed, are always more or less perfectly adapted for swimming.

The last somite of the pleon is almost universally variated from the others, and is developed much to resemble an appendage itself. It is, however, the posterior somite, and as such we designate it by the name of the *telson*.

The appendages that are attached to these several divisions are known by their relation to them. Those that are connected with the senses are determined by their character—such as the eyes, antennæ, and oral appendages.

The antennæ may be distinguished as the anterior and posterior pair, or as the auditory or olfactory respectively, in preference to that of the inner and outer or upper and lower, which is liable to vary. So the fourth pair of appendages, or the first belonging to the oral group, may be known (from their mandibular power) as the *mandibles*, while the three following may be determined by their relationship as the first, second, and third pair of *maxillæ*, or, as Professor Westwood has suggested, *siagnopoda*.

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* For the derivation of these terms see Report of the British Edriophthalmia, 1855.

The appendages of the second division, or seven pairs of legs attached to the pereion, may be readily denominated the *pereiopoda*; but the anterior two pairs are commonly variated for different purposes. In Brachyura they fulfil the purposes of opercula to the mouth; in the Squillidæ and Edriophthalmic Crustacea they are adapted for prehensile and ambulatory purposes; so that it may be found convenient to recognize them by a distinctive name, as *gnathopoda*.

The appendages of the third division, or pleon, are never developed for walking or prehension, but almost universally are formed for swimming; and even in the Isopoda, where these are utilized as branchial organs, they occasionally fulfil the office of swimming-appendages. Not unfrequently the last two, as in the Macrura, and the last three, as in Amphipoda, are variated in form so as to enable the animal to spring when on land or dart a considerable distance in the water; and the term *uropoda* has been applied to them; but their variation is so inconstant that the advantage of defining them by any special name will be less than the convenience arising from the distinction.

The integumentary structure is one of the most important in the Crustacea, and a knowledge of the variations of its several parts is of much assistance, not only to the student of the history of these animals, but also for elucidating the knowledge of those forms that have passed away and can be studied only through the impressions left imbedded in the rocks.

The external skeleton of a crustaceous animal consists of series of rings, that appear to repeat each other, differing only in modification according to the necessity of the various portions of the animal. These rings represent and protect externally various segments of the body, each division supporting one pair of appendages only and the internal structure that relates to them. Each of these several divisions we call a "somite," a term suggested, I believe, by Professor Huxley in his lectures at the Royal College of Surgeons. Of these there are never more than twenty-one; and this may be considered as being the normal number in all Crustacea above those known as the Entomostraca, in some few of which, as in the genera *Apus* and *Stegocephalus*, the number of somites appear to be much more numerous; but there the somites appear to be repeated without having any function to fulfil or appendage to support—a numerical repetition only, the result of an enfeebled force.

The first somite supports and carries the organs of vision. In some of the most condensed forms the eyes are implanted on the outer side of the two pairs of antennæ; but the internal structure invariably shows that the most anterior pair of nerves are those that are connected with these organs. The progress of development which we purpose alluding to in its proper place clearly demonstrates the eyes to be the most anterior of all the organs.

The second somite bears the first pair of antennæ, which, from its position in the higher Crustacea, is generally called the inner pair, and from its position in the lower forms is called the upper pair of antennæ.

The third somite supports the second or posterior pair of antennæ; this, from its relative position to the other antennæ in the higher and lower forms of Crustacea, has been called respectively the outer and lower antennæ. This somite is so closely associated with the fourth that it is not certain that they exist distinct in any species of Crustacea.

The three anterior somites are generally closely blended together. In the earlier forms of development they are invariably so; but in *Squilla* and its congeners the two anterior somites are distinctly separated from each other and the third. In *Palinurus* the first is distinct from the second; but in the greater portion of Brachyurous and Macrurous Crustacea the three first somites, and perhaps the fourth, are strongly soldered into one piece.

This piece in most Crustacea, but more conspicuously so in the more condensed forms, is developed to a greater or less extent, and is recognized under the name of the carapace or shield.

In the lower forms, such as the Amphipoda and Isopoda, it is developed sufficiently to cover only the four succeeding somites; while in the higher forms, such as the Brachyura, it is developed so as to protect the whole of the animal.

The carapace varies very much in shape, both in width and length, and generally covers the whole of the somites of the pereion; but not universally so. In the Anomura several genera have the posterior somite of the pereion exposed; in the Diastylidæ there are three or four somites not covered, and in the Edriophthalmic Crustacea all seven are unprotected and developed into perfect somites.

It is one of the earliest features present in the development of the embryo, and is distinctly defined in the *Nauplius* form. Even in this early stage of development, as in later existence, the form of the carapace varies considerably, and is an easy mark of distinction between genera. It is desirable as well as important, in an anatomical point of view, that a clear idea should be obtained of the homological relation of this large and conspicuous portion of the highly developed crustacean. This can be done only after an examination and comparison of a large number of various forms and types of animals, as well as a close investigation and study of the parts during their progressive development.

Milne-Edwards, as far back as 1834, arrived at the conclusion that the carapace in the higher types of Crustacea is "the result of an excessive development of the superior arch of the cephalic antenno-maxillary segment. . . . But (Hist. des Crust. vol. i. p. 26) among certain Stomapods, such as *Squilla*, the head is divided into many distinct segments; the first two, the ophthalmic and antennular rings, are movable and little developed. The third and fourth rings are, on the contrary, very large and compose between them a single segment that we call the antenno-maxillary. The carapace occupies the dorsal portion of the *tronçon* formed by this union, and is prolonged above the six following rings."

"In studying (*l. c.* p. 28) the carapace as a whole as well as in its parts, we must examine into the rules of the normal organization of Crustacea, not only in the later, more or less, remarkable modification, but also the very curious structure of certain Entomostraca, where all the animal is enclosed in a kind of bivalve shell."

These views receive general support from Mr. Dana, who, however, takes exception to the assertion that the ventral piece of the carapace is formed out of what M. Milne-Edwards calls the epimera (*l. c.* p. 32), but contends that they "are in fact the posterior extension of the mandibular segment;" and he continues, "excepting that we consider what is here called epimeral, the mandibular segment, we agree with Milne-Edwards, for the most part, in the above-mentioned deduction; so that while the mandibular segment is confined to the ventral pieces of the Brachyural carapax, it constitutes its posterior half in Macrura."

In 1855 the author of this Report communicated to the 'Annals of Natural History' a memoir on this subject, supporting the opinion of Milne-Edwards as to the homology of the carapace, but denying the existence of epimera in the theory of the somite, and corroborating the assertion of Dana that the antennal segment constitutes the anterior and upper portion, and the mandibular segment the posterior and lower portion of the carapace in the Macrura and Brachyura; and affirmed that the suture which traverses the lower surface forms a line of demarcation between the third and fourth somites; it homologizes with the cervical suture in the Macrura, as also with that which traverses the dorsal surface of the cephalon in several genera of Trilobites (Pl. I. fig. 5).

If we wish to judge of the relation of these parts in the several forms of Crustacea, we must make a careful investigation during the immature stages of the animal.

In the *Megalopa* stage the inferior antennæ are attached to the anterior external horns of the carapace; these horns are folded beneath the animal, and it is this inflection that forms the orbit in which the eye is lodged. Through this inversion, consequent upon the monstrous development of the hepatic region, this suture lies upon the inferior surface of the carapace in Brachyurous Crustacea, extending posteriorly to the extreme limits of the carapace.

The author concluded his paper by saying, "But we have seen in the descending scale of nervous force the rings which carry the organs of consciousness degenerate in importance, and yield to a corresponding development of the mandibular ring: this law appears to be in force in the Amphipoda, the lowest type of the Macrura form, in which I am inclined to believe that the mandibular ring represents the whole of the upper portion of the cephalic articulation—the anterior three being so diminished in importance, that they are to be found only in the perpendicular wall of the head, or perhaps represented by their appendages only" (Ann. Nat. Hist., July 1855).

It would scarcely perhaps be necessary to enter further into the evidence that supports the homological relations of the carapace, had not Professor Huxley, in his Hunterian Lectures at the Royal College of Surgeons, expressed an opinion opposed to the above statements.

In his twelfth lecture Prof. Huxley says:—"In all the Brachyura and ordinary Macrura it appears to me to be obvious that the carapace is continuous with, and part of, all the somites of the cephalothorax—that it is composed, in fact, of their connate terga, the branchiostegite being nothing more than their connate and highly developed pleura; the cervical suture, placed immediately behind the attachment of the mandibular muscles and in front of the heart, corresponds in these respects precisely with the posterior boundary of the head of a *Squilla* and of a Branchiopod, or of an Edriophthalmian. The cephalic arc roofs over the stomach, as does the tergal region of the head in these last-named Crustacea. Anatomically, then, it seems to be demonstrable that the scapular arc of the carapace in the ordinary Podophthalmia is the equivalent of the terga of the thorax, that the cephalic arc is the homologue of the terga of the head, and that the carapace is formed by all the cephalothoracic somites."

Before the Reporter can proceed with any fresh evidence to support the argument demonstrative of the homological character of the carapace, it is desirable that a clear idea should be given of the theory of a somite or segment as it exists in Crustacea.

Prof. Milne-Edwards, in his 'Histoire des Crustacés,' vol. i. p. 16, says:—"Each of the rings of the skeleton appears to be composed of two lateral moieties, resembling each other. We can distinguish moreover two arcs, the one superior, the other inferior, as shown in the accompanying diagram [pl. 1. fig. 3 of his work]. The former results from the assemblage of four pieces more or less intimately connected together, and arranged in pairs on each side of the median line. The central pieces are called by the name of the *tergum*, and the lateral are called the *flancs* or epimeral pieces. The inferior arc is composed of the same number of pieces. The two median pieces unite to form the *sternum*; and the latter are known by the name of the *episternum*, by reason of their analogy with those that M. Audouin has designated by the same name among insects. They are united always at the sternum; but there generally exists, between the inferior arc and the epimera situated above, a wide space destined for the articulation of the corresponding member."

"We know of no example," he continues, "of a ring where we are able to distinguish at the same time all the pieces that we desire to enumerate. Sometimes there is an absence of some of the pieces from the place they should occupy, and sometimes they are very intimately soldered together, so that we cannot see even a trace of separation; but in studying each of them separately, where it is most distinct, we shall be able to form a clear idea, and recognize its character in spite of its union with its neighbouring pieces. Moreover, although this analysis of the ring may not be always practicable, it is not the least true that it facilitates much the study of the exterior skeleton of articulated animals, and that it will permit us often to establish analogies where there would first appear to exist the greatest difference."

"To terminate the enumeration of the constituent parts of the tegumentary rings of the Crustacea, there only remains for us to speak of the plates that we often see elevated from the internal surface and arrange themselves into cells and canals. These processes are always developed at the points of union of two rings or of two neighbouring pieces of the same segment; and this disposition has obtained for them the name of apodemes (from M. Audouin). They are the result of a fold of the integumentary membrane which penetrates more or less deeply between the organs, and which is strengthened with calcareous matter like the rest of the structure, and are always formed of two thin plates soldered together."

These views have long been accepted as the acknowledged theory. Nor am I aware that any one (except the authors above quoted) has attempted upon original investigation to analyze the evidence upon which M. Milne-Edwards has formed his theory.

That the author of this Report has long held views not consistent with M. Milne-Edwards's theory, is known to those carcinologists who have read his Report on the British Edriophthalmia, which was communicated to this Association and published in its Transactions for 1855, wherein he trusts that he clearly demonstrated that the pieces to which M. Milne-Edwards gave the name of *epimera*, and selected by him as typical of his theory, were parts attached to the legs, and not pieces of the dorsal arc of the crustacean somite.

He is moreover desirous in this Report to show:—that the epimera, as sectional pieces in a theoretical construction of a somite, cannot exist; that the so-called epimera are portions only of the integumentary structure of the appendages of the animal, and that the apodema are formed out of this structure, more or less thinned out by lateral pressure and internal arrangement; and that the head of the lower types and carapace of the higher are homologically the same, the carapace being a monstrous development intended for the covering and protection of the more complicated branchial appendages of the higher types.

But this portion will be discussed more fully when the structure of the appendages is treated of.

The earliest stage in the life of a crustaceous animal, in which the dorsal shield known as the carapace is observable, is that of the young as it exists fresh from the ovum of a cirriped (Pl. I. fig. 1). This, which has been named the *Nauplius* form of the Crustacea by Fritz Müller, exists as a small animal with three pairs of appendages only. The eyes are not developed, the ocular spot not being homologous with the permanent organs; but since we see that material does enter into the stomach, we can have no great effort in accepting the proposition that this incipient animal has a mouth; and such being the case, we must assume that the anterior four somites are present in the construction of the head of the *Nauplius* stage of Crustacea. The oral apparatus is still in an embryonic condition.

The next stage of living types in which we can observe the carapace to exist in the progressive condition is in that known as the *Zoëa* form of Crustacea (Pl. I. fig. 2). This is the early life of the young of the higher Podophthalmous Crustacea. That of the Brachyura is most known and most instructive. Some of the appendages are beginning to assume a permanent form. The eyes are developed, the antennæ (though in an immature condition) are in existence, and so are all the appendages of the head except the last. The first two pairs of appendages connected with the pereion are present in an immature condition, and the posterior pairs are represented by small bud-like appendages. Dissection readily demonstrates that the carapace in this stage only covers, but has no associated connexion with, the appendages of the pereion; and a closer study shows that the heart is connected with and partly exists in the great dorsal spine. The relative position of this process, therefore, enables us to determine that the future growth of the carapace takes place and is connected with the anterior portion of this structure, and not with the posterior. In the young of *Palinurus*, as well as in the larger forms known as *Phyllosoma*, which appears to be the young of *Palinurus* older in age and larger in size, the carapace is developed largely in advance of the oral apparatus; it is produced posteriorly so far as to project over the anterior two somites of the pereion, but is not attached to any portion beyond the posterior oral appendages. An examination of the *Zoëa* of the various types of Podophthalmous Crustacea supports this observation; and we can trace the same facts from the *Zoëa*, through the *Megalopa*, to the adult Brachyurous Crustacea (Pl. I. fig. 3). It is therefore desirable that we should see how far the study of an adult crustacean will assist us in demonstrating the true relation of the carapace to the general structure of the animal.

In *Squilla* and allied forms of the same type the two anterior somites (the first of which supports the eyes, the second the anterior pair of antennæ) exist as distinct and perfect, though small somites; whereas the two succeeding are closely associated together, and appear as a large dorsal plate supporting the posterior pair of antennæ and mandibles. The posterior three somites belonging to the cephalon and the first two belonging to the pereion are represented by the sternal plates only. In the young forms the anterior two somites belonging to the pereion are in a membranous condition dorsally complete.

According to the theory of Professor Huxley, the carapace represents the dorsal arc of all the somites that it protects and have not a distinct roof of their own.

It is therefore desirable that we should learn what may be the distinct useful value of the carapace, and why each somite would not serve the same purpose by being perfect in its own arc.

The branchial organs, that are so essential to the aeration of the blood in all aquatic animals, are in the Crustacea appendages attached to the members belonging either to the pereion or pleon or both. In the lower and terrestrial types, such as the Isopoda, they are connected with the pleon only. In some Stomapods, as *Squilla* and its allies, we find them attached to the pleopoda as well as the pereiopoda; but in the higher groups they are invariably attached to the pereiopoda only. In the most simple form the branchiæ exist as mere saccular attachments, whereas in the higher types they become more complicated and voluminous. In the saccular condition they are held by a small neck pendent from the joint, and are exposed in the water without protection; but in the higher Podophthalmous types they are formed of very numerous plates folded close together upon a central stalk, and would be very liable to injury if not protected by some means.

The branchiæ, therefore, being in their very nature external organs, and attached to the first joints of the several appendages of the pereion, it is self-evident that they could not be covered or protected by their own somite, inasmuch as if it had passed over them the branchial appendages would become internal. Their character and constitution would therefore be changed; they would cease to be external; in fact they would cease to be branchiæ.

But since the appendages exist as branchiæ and are covered and protected, it must follow that if the protection cannot be evolved from the somites to which they are secondarily attached, the covering must be the result of the development of some other somite.

The somites in their simple conditions have a tendency to overlap one another to an extent that precludes them from permitting any portion of the intermediate structure being exposed.

That the somites have a tendency to extend in every direction, is very evident from the different proportions and forms they severally undergo in various genera, and those which compose the carapace exist in all proportions.

In the Isopoda the cephalon is reduced to the smallest extent in a typical form of Crustacea. In the Amphipoda the cephalon is much larger than in the Isopoda; but in neither of these is the integumentary covering produced to cover or protect any somite that is not included within its anatomical bounds. In the Diastylidæ, one of the lowest forms of the Schizopod type (where the branchiæ consist of but one or two pairs of a multicellular form), the tergal projection of the cephalon extends posteriorly over half the pereion; whereas the lateral walls are anteriorly produced, so as to protect and cover the anterior cephalic appendages. These animals burrow and live in the mud and sand; and no doubt this development of the carapace forms a good protection to the eyes and antennal organs. Thus we can readily interpret the origin and homologue of the shell-covering in *Limnadia*, *Cypris*, &c., by supposing a monstrous development of the carapace in every direction, induced as a protection to a feeble animal that but for this protection must perish in its destructive habitat.

In *Squilla* and its allies (the typical form on which Milne-Edwards has based his researches) the carapace does not extend posteriorly beyond its anatomical bounds; laterally it projects interiorly more so; but the great size of this plate arises from the large amount of space that exists between the mandibles and the antennæ; and as a carapace it is scarcely more important than the tergal surface of the cephalon in the Amphipoda. The branchial organs in this type of animals are saccular, or more rudimentary in their condition than the same organs attached to the pleon. The carapace as a covering is not required to protect these branchial organs, which are not more important than the same in the Amphipoda. Gradually, as the branchiæ assume a more complicated or multicellular condition, the carapace increases in dimensions both laterally and dorsally, until we perceive it reaches the important feature we find in the Brachyurous Crustacea.

In *Squilla* the eyes are borne on a distinct somite; in *Palinurus* the same is distinctly visible; in *Cancer* the ophthalmic somite is likewise distinct and separated from the next succeeding, but it is wrapt over and enclosed by the next or anterior antennal somite. In *Squilla* also the first pair of antennæ are borne on a somite distinct from the succeeding. In the Macrura and Brachyura this and the succeeding somites are closely blended together; but in *Squilla* the fifth, sixth, and seventh somites are capable of being determined by their sternal pieces only. As we perceive the tergal pieces of the somites of the pereion are wanting in the Brachyura, so we may assume that they are not developed in the posterior somites of the head in *Squilla* under similar conditions. There therefore is every reason to believe in the theory, that the monstrous development of the mandibular and posterior antennal somites, incorporated together, unite to form the perfect carapace that is so characteristic of the typical Crustacea.

But whatever may be correct in a theoretical or transcendental point of view, for all anatomical and practical requirements the carapace represents the tergal surface of the cephalon, so largely developed as to cover and protect not only the pereion, but, as in *Cryptolithodes*, the entire animal.

In the development of the Crustacea the gradual progress of the carapace may be traced through all its stages.

In the ovum the members are first represented by small gemmiparous sacs, and precede the formation of the dorsal or ventral arcs in the small *Nauplius*. The carapace covers and protects all the animal except the pleon; but this represents only the four anterior somites and their appendages. In the *Zoëa* stage the carapace is perfect and folded downwards laterally, and is capable of covering and protecting all the appendages of the cephalon and the anterior two of the pereion. At this period no branchial organs exist, but saccular appendages in an embryonic condition are budding in their places: in a short time the pereiopoda are seen to form, and the branchial organs assume a definite character; and with their appearance a change takes place in the form of the carapace.

In a large number of Brachyural *Zoëæ* a more or less conspicuous spine or tooth-like process may be seen to occupy a position on the lateral walls. This spine, from observation during the progressive growth of the animal, is seen to correspond with the angle in the adult that defines the demarcation between the branchial and hepatic regions. The deflection of the carapace anteriorly bends over the hepatic lobes, the line of the greatest curvature being frequently surmounted by a series of well-defined tooth-like cusps; and posteriorly bends over the branchial organs, the curvature here being less abrupt and seldom surmounted by any cusp or process.

Externally the carapace covers and protects both the hepatic and branchial organs; but internally a calcareous wall of demarcation exists.

This wall, which Milne-Edwards terms the apodema, is continued into a thin membranous tissue that makes a distinct and well-defined separation between the branchial appendages and the internal system; so that the aqueous element, so necessary for the aeration of the blood as it passes through the branchiæ, may have full power to play upon the gills without having any passage that would admit it to the internal viscera and derange the general economy of the animal.

Not only does the carapace vary in external form, but also in the configuration of its surface. The relation that it holds to the internal viscera is to afford protection and means of support.

When the former only is required, the structure is generally smooth and even; where the tissues are internally thicker and irregular, it gives to the external surface an indented and irregular aspect, which is common, particularly in the flat and short-tailed Crustacea, where the markings are so persistent as to afford a very valuable assistance for the determination of species.

These markings are generally induced by the attachments of the tissues that secure certain viscera in their positions; these form generally points of depression; but where any organ (such as the liver, stomach, or branchial appendages) is protected, the corresponding points in the carapace are elevations, sometimes crowned with a pointed spine or process. The branchial appendages are external in relation to the body of the animal, but covered over and protected by the lateral walls of the carapace. To complete this so as effectually to protect those organs without pressing on or interfering with their functions, a very considerable amount of lateral development has taken place, and a peculiar reflection so as to bring the margin of the carapace below the branchial appendages and to protect them from rude contact with the limbs. The angle which is induced by this inflection of the carapace over the hepatic lobes and enclosing the branchiæ is generally well defined and ornamented with points or processes more or less numerous. These processes define the dorsal limits of the carapace.

Desmarest, half a century since, mapped out the dorsal surface of the carapace into regions coinciding with the limits of the internal viscera.

Milne-Edwards, in his 'Histoire des Crustacés,' published in 1839, adopted the same views, supporting it by illustrations from several genera.

Professor Dana more recently, in his great work on Crustacea, has divided the dorsal surface into many more regions, taking the numerous areolites that are present in some genera (as *Zozymus*).

He divides the carapace by a transverse line that extends from just anterior to the last of the normal lateral teeth to the same on the opposite side, and separates it into anterior and posterior portions.

The anterior he again divides into three parts, defined by lines of depression, and names them the median region and two antero-lateral regions.

The median region covers the stomach, and includes the gastric and genital regions of Desmarest.

The space anterior to the median region he calls the frontal, and on either side the orbits form another, which may be called the orbital region.

The posterior portion of the carapace he likewise divides into a posterior and two postero-lateral regions.

Professor Milne-Edwards in 1854 readdressed himself to this subject and further elaborated it. In the 'Annales des Sciences Naturelles' he communicated his researches with illustrations from several genera, and divided the dorsal surface of the carapace into regions corresponding with the names of the internal viscera. But it appears to me that the correspondence in many parts exists in the name only; as, for instance, in the gastric region, which he subdivides into epigastric or anterior lobes of the gastric region, protogastric or latero-anterior lobes, mesogastric or median lobe, metagastric or latero-posterior lobes, and urogastric or medio-posterior lobe of the gastric region.

It is quite within the power of demonstration to prove that it is more in accordance with the correct anatomical details of the animal's structure if the lobes that he named metagastric, or latero-posterior lobes, were called, according to Desmarest, the genital regions after the viscera they protect. And no advantage appears to me to be derived from dividing a region into parts that are not constant, and when present do not represent any internal organization, as he has done in dividing the branchial region into:—epibranchial, or anterior division of the branchial region; the mesobranchial and metabranchial divisions, which consist of lobes variable in form, but represented in most genera by a smooth surface.

The cardiac region he divides into an anterior and posterior portion. The anterior alone represents the position of the heart; the posterior represents the part that lies between the heart and the posterior margin of the carapace.

The hepatic regions he does not subdivide, but circumscribes their limits within the extent of the internal organ—an object of consideration, as it appears that the extent of this organ is one of the most important features in the moulding of generic forms. The other regions are those situated on the ventral surface, and which will be considered in a future Report.

The value of a clearly defined knowledge of the various markings that are represented on the dorsal surface of the carapace of Crustacea is best appreciated in the study of fossil specimens, where the remains of animals, however well preserved, can be read by their external features only.

It is therefore with a view to accelerate this that I have in this Report endeavoured to lay down the several regions that are represented by the markings exhibited on the surface of the carapace.

Taking advantage of the information conveyed by studying the labours of the previously mentioned eminent carcinologists, I have laid it down as a rule for guidance, that the external markings must define the internal structure; and where this is not the case the lobe or projection exists as an excrescence.

The most important and constant divisions are:—

The anterior, which lies immediately above the antero-œsophageal ganglion. This may readily be subdivided into the orbital and antennal portions. The entire region, from its relation to those organs from which alone intelligence is derived, may be termed the cephalic region.

Directly posterior to the cephalic region is the gastric; this is generally very conspicuous, the intensity of the postero-lateral markings being rendered more distinguishable by the inner surface of the carapace being adapted for the attachment of the anterior tendon of the mandibles.

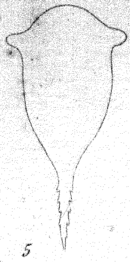
The stomach consists, in the more perfectly developed types, of a large central chamber, the form of which not only varies in genera, but is capable of extension and of being collapsed in the same individual. It has also antero-lateral cavities and a posterior or pyloric extension; but these are produced at a lower line, and therefore liable to be less conspicuously represented on the dorsal surface.

The lobe which M. Milne-Edwards has termed the mesogastric, corresponds with that portion of the stomach that is projected above the gizzard-like plates that stand at the entrance of the pyloric chamber.

On each side of the pyloric or mesogastric lobe are two generally well-defined lobes that correspond, and are probably induced by the presence beneath of the genital apparatus in the male and the commencement of the ovaries in the female. I think, therefore, that it is desirable to retain for these lobes the name that was first bestowed upon them by Desmarest, and call them the genital regions.

Posterior to these comes the cardiac region, which corresponds very closely with that of the heart, which lies immediately beneath it.

Posterior to the heart the carapace protects no distinct viscera; but the posterior margin covers the anterior half of the first somite of the pleon. The muscular system which moves the pleon is attached to the apodema that divides the cardiac from the branchial cavities, which also affords attachment



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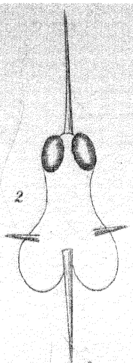

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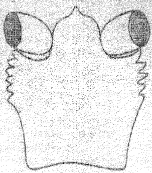

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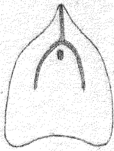

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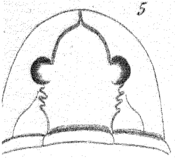

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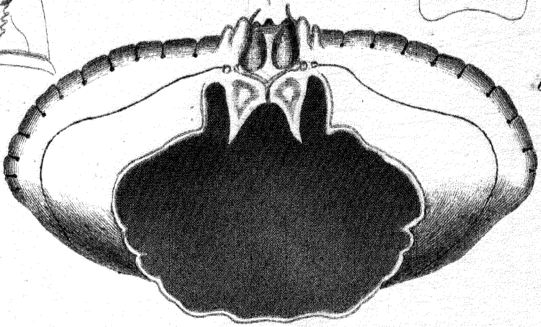

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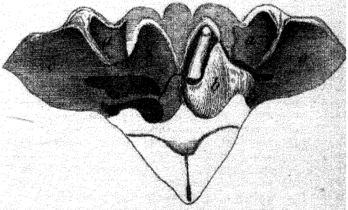

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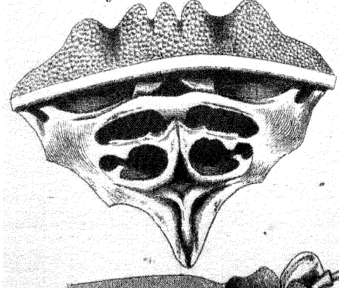

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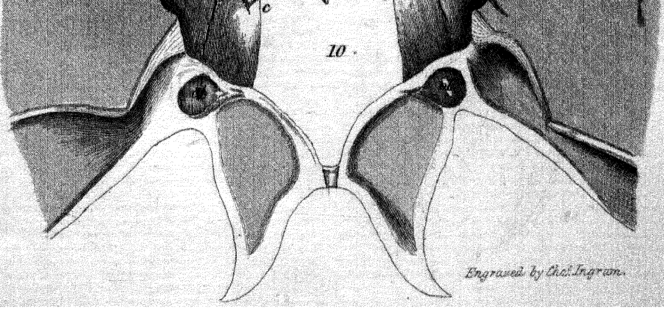

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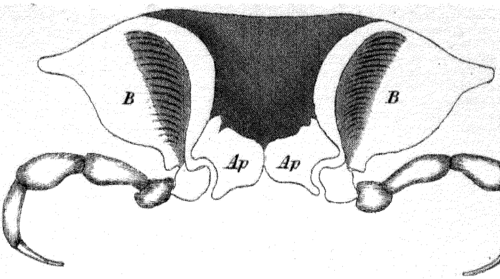

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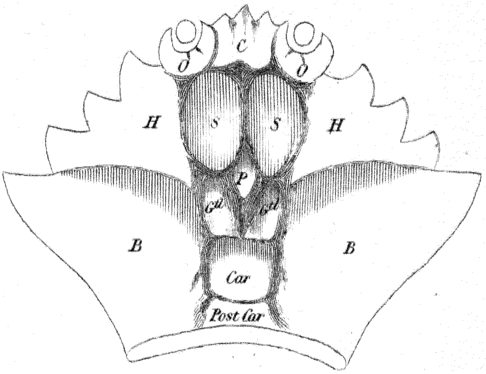

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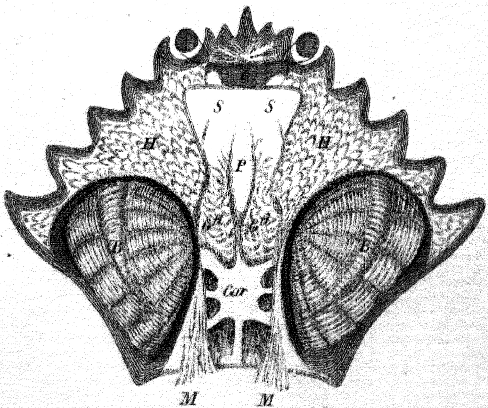

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to the extensive membrane that protects the internal viscera from the introduction of the water. This membrane is continuous with and attached to the inner surface of the posterior margin, and is represented generally by a lobe that runs parallel with the posterior margin. This portion may conveniently be known as the postcardiac region.

The hepatic regions extend on either side from the orbital region anteriorly to the posterior tooth of the hepatic crest, and are bounded by the gastric and branchial regions. This is a larger portion than is admitted by Milne-Edwards, but it is one that corresponds with the extent of the hepatic viscera.

The branchial region reaches from the posterior tooth of the hepatic crest to the posterior margin, along which it traverses nearly to the median line on either side, and is bounded on the inner side by the cardiac and genital regions, and anteriorly by the hepatic regions, from which internally it is separated by a thin membranous partition.

These several divisions appear to me to be based upon strictly anatomical grounds, and as such may be regarded as natural divisions, the variation of which must depend upon that of structure, and therefore may be relied upon as affording characteristic distinctions.

The great consolidation of the anterior somites of the skeleton has led Prof. Dana to pronounce the centralization to amount to a cephalization of the forces; but this opens a subject of considerable extent and interest, which, if permitted, I hope to present in a continuation of this Report at the next Meeting of the Association.

EXPLANATION OF THE PLATES.

References in each Plate the same:—*C*, Cephalic region; *O O*, Orbital region; *S S*, Stomachic region; *P*, Pyloric region, *H H*, Hepatic region; *Gtl Gtl*, Genital region; *Car*, Cardiac region; *Post-Car*, Post-Cardiac region; *M*, Muscles connecting the pereion with the pleon.

Plate I.

Fig. 1. Carapace of *Nauplius*, or earliest larval form of Crustacea.
2. Carapace of *Zoea*, or second larval form.
3. Carapace of *Megalopa*, or third larval form.
4. Carapace of *Diastylis*.
5. Carapace of *Trilobita*, with that of *Megalopa* displayed on it, to demonstrate the homological relation of the fissure on the ventral surface of the latter with that on the dorsal surface of the former.
6. Carapace of *Cancer pagurus*.
7. First or ophthalmic somite of *Cancer*, with ophthalmic appendages and eyes attached
8. Second or anterior antennal somite, showing external or anterior surface: *a a a*, ophthalmic cavity and foramen; *b b b*, anterior antenna, cavity, and foramen.
9. Same, showing internal or posterior surface: *a*, ophthalmic foramen; *b b*, anterior antenna and foramen.
10. Posterior antennal somite, dorsal aspect; carapace removed to show the internal surface of the ventral portion of the somite: *c c*, posterior antennæ; *ol ol*, olfactory foramen.

Plate II.

Fig. 11. Diagram showing the connexion of the branchiæ with the legs and the external character of the branchial chamber in relation to the internal viscera: *B B*, branchial chambers; *Ap Ap*, apodema.
12. Dorsal surface of carapace, showing the natural portions into which it is divided.
13. The carapace removed to show the internal structure and the relation of the viscera to the external marking in fig. 12.

Second Report of a Committee, consisting of Prof. A. S. HERSCHEL, *B.A., F.R.A.S., and* G. A. LEBOUR, *F.G.S., on Experiments to determine the Thermal Conductivities of certain Rocks, showing especially the Geological Aspects of the Investigation.*

THE original object proposed to be effected by the Committee of devising a simple and direct method of determining approximately the absolute thermal conductivities of solid bodies, and especially of the rocks of most common occurrence in geological strata, has not yet been entirely carried out. But the experiments described in the last Report were repeated under new conditions, which enable the Committee to present, with more confidence than in their last Report, a list of absolute conductivities of the rocks there specified, and to add to the list examples of some further important determinations. Many uncertainties remained to be removed from the values given in the former list, the most notable of which proceeded from the looseness of the contact obtained between the points of the thermopile and the two faces of the tested plate of rock. The real difference of temperature between the two faces was not measured, but that between the air-currents round the points of the thermopile in the two sheets of velvet which pressed them against the surface of the plate. Thus difference of temperature two or three times as great as those intended to be measured (and as those which were actually observed when in a few cases the points of the thermopile were solidly cemented to the rocks) were constantly recorded. Assuming that the indications were always too great in a certain fixed proportion (determined approximately by the direct experiments made in a few certain cases), the former list of estimated absolute conductivities was compiled from the use of the velvet-covered apparatus. India-rubber faces about two millimetres (or one twelfth of an inch) in thickness are now stretched tightly over the flat faces of the cylindrical cooler and steam-boiler, and are bound down with wire, air being carefully excluded from these junctions by displacing it with a little oil. While the top of the boiler is formed of a thick, circular, brass plate a little convex (about one millimetre high in the centre) on the upper side, a tripod wooden stand, with straight legs passing through the lid of the cooler, rests upon the inner side of its base in the sockets of a flat, circular, perforated brass plate with wide lattice openings, and somewhat less in diameter than the cooler-base, between which and the base of the cooler, again, two thicknesses of coarse wire gauze are introduced, to permit free access of the water in the cooler to the inner surface of its tinned-iron base, when the central rod of the agitator, which contains the indicating thermometer, is raised and lowered frequently enough to keep the water in a constant state of motion. Two twenty-eight-pound weights, suspended from an iron link or cross bar carried by the tripod stand, communicated in this series of experiments a pressure of about 3 lbs. per square inch to the rock-plate placed for examination between the india-rubber-covered faces of the boiler and the cooler; and it was expected that the exclusion of air from round the points of the thermopile and from the junctions between the faces might be assumed under these conditions: but as india-rubber offers great resistance to the passage of heat, it was found inconvenient to use it of sufficient thickness to accomplish this directly by its elasticity*; and recourse was had, in consequence, to soft cements, to make the junctions between the surfaces air-tight. An experiment was also made with slate, by plastering the thermopile solidly to it with thin sheets of india-rubber moistened with a mixture of red-lead and oil, and testing the conductivity of the plate when, after remaining for two weeks under pressure, the cement appeared to have solidified to perfect hardness. The result in this case (391) * scarcely differed either from the estimated number for the same rock-plate (392) given in our former list, or from two other determinations (414 and 425), when, instead of the solid junction, a thin paste of boiled starch and another of red-lead and oil were used in succession to effect the junction. Two new specimens of slate, cut from one piece, and tested by the same process, with moist lutings of starch and linseed-meal to secure the junctions, gave as values of their conductivities in different experiments the rather lower numbers, apparently belonging to this different sample of the stone, 340, 346, 349. The plate of white Sicilian marble described in the last Report as presenting when tested, by attaching the thermopile to it solidly with plaster, a resulting conductivity 559, now afforded, with moist linseed luting, the number 497. Whinstone, which formerly exhibited in the same manner an absolute conductivity 312, now afforded, with linseed luting, the conductivity 333. The results obtained with moist lutings are sometimes in excess and sometimes in defect of those observed with solid junctions, and nothing necessary to be preferred in solid over liquid attachments of the surfaces to each other was found to be indicated by these preliminary trials.

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* Although thickly jacketed with a close covering of felt and fur, the cooler, containing 2½ lbs. of water, was found to lose heat to the atmosphere at the rate of 0°·0025 F. per minute for each degree of excess of its temperature above that of the surrounding air; and for an excess of 20° F., which was sometimes reached, the loss being 0°·05 F., the

The inconstancy of some determinations now attempted of new rock-specimens with the iron and palladium thermopile led to the discovery that its rolled branches produce thermoelectric currents by alteration of the condition of the pressed metal; and no annealing by heat was able to remove this serious objection. While unequally pressed parts of the wire along its branches were subjected to unknown temperatures, it was obvious that small differences of temperature could not be measured satisfactorily with the thermopile, and no reliance in respect of ultimate accuracy could be placed on the values found up to this time with the instrument in its first constructed form. German-silver wire was, however, substituted successfully for palladium in the thermopile, with which the present series of experiments were made. It consists of three rolled wires of German silver and two of iron in series, between two rolled iron-wire terminals of a Thomson's reflecting galvanometer, three junctions of the flattened helix into which they are wound upon two bracing-bars of wood being above, and three below the rock-section, which slips easily between them. A stout india-rubber collar (half an inch in thickness) surrounds the rock-section before it is placed between the wire grating of the thermopile; and similar collars round the confronting ends of the boiler and cooler make a continuous non-conducting casing of the rock-plate and of adjoining parts of the apparatus, protecting them entirely, when the pressure acts upon them and upon the lutings that connect them, from heat-communication to the outer air. Although German-silver wire (even if unflattened) produced, when slightly heated at certain

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effects of undetected external influences might become sensible were the rate of heat-transmission to be measured less than 0°·2 F. per minute. The rate actually observed with the apparatus above described was between 0°·194 with cannel-coal and 0°·400 with quartz; and in the following list of absolute conductivities the proper correction for the external air-temperature round the cooler has in every instance been applied.

* The significant figures only of the decimals representing the absolute conductivities in the following Table are here used, for brevity, to denote them.

points of its length, sensible thermoelectrical effects of local disturbing currents, which (as was also observed in the palladium wire and in some other metals which were tried) did not appear to be removed, like those of strained iron wire, by annealing at a considerable heat, yet the high electromotive force of the German-silver iron couple and the neutralizing effect of the several loops of German-silver wire, all exposed to the same temperature variations, were found, in some suitable experiments made in the process of determining the scale of the instrument's indications, to have almost entirely eliminated the influence of these small disturbing actions; and the smallest differences of temperature, of only two or three degrees, occurring in the rock-conductivity experiments could be accurately measured. Resistances of two, five, and ten ohms were included in the thermoelectric circuit successively in each experiment; and the proportionality of the galvanometer readings in these several conditions being constant, showed the constancy of the resistance, and accordingly the unvarying scale-value of the indications of the instrument for every observation; while the zero of the scale-readings could also be conveniently determined at any moment by unplugging, in the rheostat connected in the circuit, a very large resistance of 1000 ohms. Twelve, seven, and four divisions of the scale represented respectively 1° F., when the several resistances above named were used *; and three readings being taken for every temperature-difference observation, the results reduced in this proportion were accordant to one or two tenths of a degree, as long as the total resistance of the circuit had undergone no variations from accidental injuries of the connexions, and as long as the thermometric value of the scale-divisions had accordingly been preserved. The electromotive force of a German-silver iron thermopile is shown, by Prof. Tait's representation of the specific curves of these metals in his 'First approximation to a Thermoelectric Diagram,' to be at ordinary temperatures very exactly proportional to the difference of temperature between the junctions; and the temperature-differences noted in these experiments may, it is presumed, be accordingly regarded as affected by only very small errors of uncertainty. The thickness of the flattened wire (about 0·5 millim.) of the thermopile occasioned, however, even with the considerable pressure used, a certain thickness of the lutings; and it is probable that, from this cause as well as from the partial fluidity, instead of perfectly solid nature, of the cement, the temperature-differences observed somewhat exceeded those which actually existed between the faces of the tested plates. Besides the small corrections for escape of heat from the cooler to the outer air, an addition of one tenth to all the observed conductivities is made in the present list for the cooler's thermal capacity and for that of the brass foot, wire gauze, and agitator, which it enclosed, the correction for which was not included in the conductivities assigned last year. The final results in the present list are, notwithstanding this correction, somewhat inferior to those formerly observed with the thin palladium-iron thermopile, whether its attachments were solid or effected by moist cements; but in repeated experiments with that instrument on quartz and other rock-sections offering only small resistances, the results arrived at were in general so high, and at the same time so irregular, from the predominance, in measuring their small temperature-differences, of the local currents, that for this reason only a partial dependence on its generally higher indications can be placed. The

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* An accidental injury which happened to one of the solderings was thus immediately detected; and the fault having been found and repaired, when the instrument was regraduated, it was found to afford, with the above resistances in its circuit, exactly the same proportional values of the scale-indications as before.

presence of the thin layer of moist luting of linseed-meal (mixed with between three and four times its weight of water) in the new series of experiments makes it probable, on the other hand, that the absolute conductivities presented in the following list are under rather than above, and may occasionally be five, ten, or, in the better-conducting rock-specimens, possibly even twenty per cent. below their real values; but the present arrangement of the series in a progressive scale of the observed values of the conductivities may be more certainly regarded as in the main correct.

Some experiments to compare the resistances of different rock-sections with that of the luting and india-rubber faces between which they were placed, with a view of obtaining relative conducting-powers more expeditiously without the use of a thermopile, were also made; but although this

Absolute Conductivities and Resistances of Rock-Sections.

Section of rock.	Absolute conductivities in C G.S. units.		Absolute resistances (or 1 ÷ conductivity). (1875.)	Resistances in an ascending symbolic scale.	
	Thermopile with local currents. Rocks between velvet faces. (1874.)	Compensated Thermopile, moistly luted to the rocks with pressure. (1875.)		(1874*.)	(1875†.)
Opaque white quartz	. .	0·00882 0·00876 ‡	114	...	A
Slate (cut across the cleavage. Specimen A, Festiniog).	.....	0·00660	152	...	A
Calcite (white vein-stuff in mountain-limestone).	.....	0·00596	168	...	A
Kenton sandstone (thoroughly wet).	.. ...	0·00594	168	..	A
Do. (dry)	0·00489	0·00549	182	(B)	A
Grey Aberdeen granite	0·00600	0·00514	195	A	A
Irish fossil marble	0·00559	0·00488	205	B	B
Devonshire red do	0·00525	0·00469	213	B	B
Sicilian white do...	0·00559§	0·00462	216	B	B
Red Cornish serpentine	0·00483	0·00399	251	C	B
Whinstone	0·00312§	0·00366	273	D	B
Slate (cut parallel to the cleavage. Specimen A).	0·00392	0·00363	275	D	B
Do. (do. Specimen A, Festiniog).	.....	0·00325	308	...	C
Calton Hill trap-rock (from foot of the Observatory garden, Edinburgh).	0·00520	0·00332	301	(B)	C
Red brick (thoroughly wet) ..	.... .	0·00247	405	..	C
English alabaster	0·00412	0·00234	427	(C)	C
Plaster of Paris (plate, thoroughly wet).	......	0·00160	625	...	D
Red brick (dry)	. ...	0·00147	680	...	D
Plaster of Paris (plate, dry) ..	0·00163	0·00120	833	K	E
Cannel-coal	0·00161 §	0·00065	1538	K	K

* See Report, 1874, p 132. † See Diagram, page 59.

‡ Average of two equally good determinations 0·00879.

§ The conductivities marked thus were obtained by solid junctions of the thermopile to the rock-faces with plaster of Paris, the remaining numbers of the column were derived (in a constant proportion obtained from those) from conductivities observed with the thermopile pressed against the rock-surfaces by velvet faces.

method of comparison appears to be the best adapted, by its directness and simplicity, for determining relative resistances, the conditions of contact and of communication of heat across the junctions appear to be subject to so much variation that results of great discordance only have hitherto been obtained. Before abandoning a process which recommends itself by its ease and simplicity, further experiments, however, will be tried to remove if possible, from a method which promises in the sequel to become so much more expeditious, all the most influential sources of disturbance.

The unit in which the absolute conductivities are expressed is the same as that adopted (employing the centimetre, gramme, and second as its basis) in the Table of the last Report; and the absolute resistances in the fourth column of the Table are the simple reciprocals of these, or the quotient of unity divided by the absolute conductivities. As it is in the form of this quotient or of the absolute resistances that the capacities of rock-strata for conducting heat are most conveniently employed in calculation, a graphical construction, and at the same time a convenient symbolic scale of the various grades or degrees of absolute resistance presented by different species of rocks, is here annexed (p. 59), with a view of exhibiting to the eye the general extent and character of their specific variations.

Among the rock-sections re-examined, three only (Kenton sandstone, Calton trap, and English alabaster) are displaced, in the present list, from their previous order of succession. The rough and porous surface of the Kenton sandstone placing it more effectually in contact with the moist cement than the smooth surfaces of other rocks, may be accepted as an explanation of the high conductivity which it now presents; but the rough surface of the Calton trap and the smooth faces of the alabaster (although these rocks are not, like the specimen of sandstone, extremely porous) would give rise to the same or to an opposite variation; while both are lower in the list than the smooth-faced red serpentine, which has not altered its position. The defective indications of the first constructed thermopile may have introduced errors of the determinations in these latter cases, while it may probably be to its porosity alone that the Kenton sandstone now owes its somewhat superior position.

The question of the effect of porosity and of the saturation of rocks with water in increasing their conducting-power was suggested by the late Mr. W. J. Henwood as one deserving of the Committee's accurate investigation; and several observations for this purpose were made, of which the results are included in the Table. It was found that of three porous rocks examined, Kenton sandstone absorbed (when freed from air *in vacuo*) 5·7 per cent. of its weight of water, while its conductivity rose in consequence from 549 to 594, or 8 per cent. A plate of fine red building-brick, whose absorption of water was 15·6 per cent. of its weight, received by this treatment an increase of conductivity from 147 to 247, or 68 per cent.; while a plate of plaster of Paris which absorbed 26 per cent. of its weight of water, rose in its conductivity by the saturation from 120 to 160, or not more than about 33 per cent. There is no appearance of regularity in these increases, but to a more copious saturation with water it is evident that a higher proportion of increase of the conductivity is connected; and again, comparing the highly conducting sandstone and the badly conducting brick or plaster, it is also evident that to every percentage weight or measure of water absorbed by the badly conducting substances, there corresponds a considerably greater percentage increase of the conductivity than for the absorption of the same percentage quantity of water by the better conductor. That this may arise

Rock-plates (dry or wet), and the Directions of their Planes of Section.

	Thermal resistances.	A		B		C		D		E		F		G		H	
		100	200	300	400	500	600	700	800	900	1000	1100	1200	1300	1400	1500	1600
1. Opaque white quartz	114	......	*														
2. Slate (across cleavage)	152	......	*														
3. Calcite (vein-stuff)	168	......	*														
4. Kenton sandstone (wet)	168	......	*														
5. Kenton sandstone (dry)	182	......	*														
6. Grey Aberdeen granite	195	......	*														
7. Irish fossil marble	205	......	......	*													
8. Devonshire red marble	213	......	......	*													
9. Sicilian white marble	216	......	......	*													
10. Red Cornish serpentine	251	......	......	*													
11. Basalt (Whinstone)	273	......	......	*													
12. Slate (with cleavage), *a*	275	......	......	*													
13. Calton Hill trap	301	......	......	......	*												
14. Slate (with cleavage), *b*	308	......	......	......	*												
15. Red brick (thoroughly wet)	405	......	......	......	......	*											
16. English alabaster	427	......	......	......	......	*											
17. Plaster of Paris (thoroughly wet)	625	......	......	......	......	......	......	*									
18. Red brick (dry)	680	......	......	......	......	......	......	*									
19. Plaster of Paris (dry)	833	......	......	......	......	......	......	......	......	*							
20. Cannel-coal	1538	......	......	......	......	......	......	......	......	......	......	......	......	......	......	......	*

from appreciably good conductivity of water itself may be inferred with some degree of probability from the observations of Prof. Guthrie*, that films of water offer from four to fifteen times *less* resistance to the passage of heat through them than those of any other liquid (mercury excepted) of whose relative thermal resistances he obtained determinations. From Dr. Sterry Hunt's recent publication† the following Table of porosities and densities of various rocks is extracted, showing to what extent the presence of water among such strata may be expected, according to the general conclusions, to affect their thermal conductivities and to diminish their resistances.

Table of Densities and Porosities of certain Rocks.

Description of rock.	Density (real specific gravity).	Absorption of water by 100 volumes of rock.	average
1. Sandstone (Potsdam) (hard and white)	2 644	1·39	2·21
2. Do. do.	2·638	2·72	
3. Do. do.	2·633	2·26	
4. Do. do.	2 618	2 47	
5. Do. (with *Scolithus*)	2·636	6·94	8·06
6. Do. do.	2 641	7·90	
7. Do. (with *Lingula*).	2 611	9 35	
8. Do. Sillery (green argillaceous). ...	2·795	2 73	2·79
9. Do. do.	2·719	2·85	
10. Do. Medina (red argillaceous) ...	2 767	8 37	9 21
11. Do. do.	2 776	10·06	
12. Do. Devonian (fine grey)	2·646	20·24	20 71
13. Do. do.	2·645	20·64	
14. Do. do.	2·649	21·27	
15. Shale, Sillery (red argillaceous).	2·784	3 96	
16. Do. Hudson's River (black argillaceous).	2·747	0 30	
17. Do. Utica (Pyroschist)	2·334	0 75	1·26
18. Do. do.	2·396	0·93	
19. Do. do.	2·421	2·10	

Description of rock.	Density (real specific gravity).	Absorption of water by 100 volumes of rock.	average
20. Limestone, Trenton (black compact)	2 714	0 30	
21. Do. (grey compact).	2·715	0·32	
22. Do. (crystalline).	2·673	1·16	1·40
23. Do. do.	2 708	1·34	
24. Do. do.	2·684	1·70	
25. Dolomite (Niagara).	2·679	5·27	
26. Do. (Calciferous)	2·833	2·15	4·88
27. Do. do.	2 838	2·53	
28. Do. do.	2·822	6·61	
29. Do. do.	2·832	7 22	
30. Do. (Guelph) ...	2 829	10·60	10·32
31. Do. do.	2·810	10 04	
32. Do. (Onondaga)	2·825	10·92	
33. Do. Chazy (argillaceous)	2·824	13 55	—
34. Do. do.	2·823	3·75	
35. Do. do.	2·825	4 69	
36. Do. do.	2 891	10·12	
37. Caen limestone	2·637	29·49	28 65
38. Do. do.	2·644	26·93	
39. Do. do.	2·611	29·54	

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* Philosophical Transactions of the Royal Society, 1869, part 1, p. 659 (Table).

† Chemical and Geological Essays, by Prof. T. Sterry Hunt, p. 166 (1875). This is reprinted from the Report of the Geological Survey of Canada for 1863–66, pp. 281–283. By an oversight in this Table the Caen limestone is described as *Tertiary* by Dr. Sterry Hunt instead of Secondary.

Another subject of important applications in questions relating to underground temperature which has engaged the attention of the Committee, is the different degrees of facility with which some rocks conduct heat in different directions, recent researches by M. E. Jannettaz having shown that this property is possessed not only (as was long since shown by De Sénarmont) by certain crystals, but also by other mineral substances, and in a very high degree by rocks having schistose and laminated structures. To verify this important fact, specimens of Welsh slate were prepared by cutting plates from the same piece across and parallel to the plane of cleavage; and the rate of conduction of heat through the plates cut in the former manner was found to be nearly twice as rapid as that through plates cut parallel to the cleavage-plane. Thus the resistance of slate (shown in the Table) to transmission of heat along the cleavage-planes is only half as great as that offered to its passage across them. The example of this slate is not an exceptional one among laminated or schistose rocks; and the extreme ratios of the resistances in the parallel and transverse directions to the planes of cleavage or foliation, which have been studied and measured by M. Jannettaz * in a variety of cases, exhibit some much more remarkable proportions.

Description of rock.	Ratio of *axes* of the observed ellipses. Paral. diam.: transv. do.	Extreme ratio of the conductivities. Parallel : transverse.
1. Steaschist, U. S. A (light green, in powder very unctuous to the touch)	2·007 : 1	4·028 : 1
2. *Phyllade* (slate), Deville, Ardennes, France	1·988 : 1	3·952 : 1
3. Fine-grained mica-schist, Aurillac, Cantal, France	1·82 : 1	3·312 : 1
4. Talcose schist, French Guyana	1·78 : 1	3·168 : 1
5. *Phyllade* (slate), Angers, France	1·6 : 1	2·56 : 1
6. Gneiss, with fine crystals irregularly placed	1·2 : 1	1·44 : 1
7. Gneiss, the crystals giving a veined appearance, Lyons, France	1·00 : 1 (circular).	1·00 : 1
8. Serpentine, with curved veins	1·15 : 1 (the longer diameter always in the direction of the veins).	1·323 : 1

The method of experiment adopted by M. Jannettaz is that originally employed by De Sénarmont, of coating thin sections of crystals with grease or wax, and observing the ratio of the diameters of the oval figures formed on their surfaces by the melted grease round a point which is heated at the centre of the plate. In a series of earlier experiments † on thin plates of crystals, M. Jannettaz had determined the ratios of the diameters for forty or fifty mineralogical species; and the values of these ratios are included ‡, with only rare exceptions, between 1 and 1·3 : 1. The ratios of the conductivities in the directions of those diameters, being the squares of the ratios of the measured axes, range in value, for the majority of crystals, between 1 and 1·7 : 1, and rarely approach the values above given for some of the talcose and schistose rocks. It is shown in his researches that the principal axes of conductivity in crystals are more closely related to the planes of cleavage than to either the optic or the crystallographic axes, and that in rocks of schistose structure it is to the internal texture arising from pressure in metamorphic actions rather than to crystalline admixtures, giving to some rocks a regularly streaked or veined appearance, that the principal development of the property of unequal thermal conductivity in different directions presented by this numerous class of rocks should be ascribed. These new considerations, and the further recognition of the important part which the saturation of certain rocks with water must exercise in determining the distribution of underground temperature in certain cases, together with the observation, recorded in the Table of this Report, of the extremely high conductivity of quartz forming compact masses in the neighbourhood of underground workings, in some situations of considerable extent, are points of special interest connected with the progress of this inquiry, the applications and extensions of which, should the Committee pursue this inquiry further, will form the chief object of their immediate investigations.

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* Bulletin de la Société Géologique de France, tome ii. p. 264 (April–June 1874).

† Annales de Chimie et de Physique, série 4, tome xxix. (1873).

‡ The cases of ratios excepted from the above limitation are those of the following metals or minerals having either two or three *principal axes* of conduction:—Quartz, 1·312 : 1; amphibole hornblende and tremolite, 1·42 and 1·67 : 1; selenite, 1·54 : 1; metallic antimony (rhombohedral), 1·59 : 1; antimonite, 1·836 : 1·451 : 1; mica, 2·5 or 2·4 . 2·4 or 2·3 : 1. The extreme ratio of good to bad *conductivity* in mica is 5·76 or 6·25 : 1; and, as in selenite and in some other crystals possessing very distinct cleavages, the direction of good conduction is along and that of bad conduction is across the cleavage-planes.

Preliminary Report of the Committee, consisting of Professors ROSCOE, BALFOUR STEWART, *and* THORPE, *appointed for the purpose of extending the observations on the Specific Volumes of Liquids. Drawn up by* T. E. THORPE.

WE are indebted to the experimental and critical labours of Hermann Kopp for the greater part of what we know concerning the relations between the specific gravities of liquids and their chemical composition. Kopp has pointed out that when the specific volumes of liquids are compared at temperatures at which their vapour-tensions are equal, as at their boiling-points, several remarkable relations manifest themselves. In the first place, it is found that the specific volume of a liquid formed by the union of two other liquids is equal to the sum of the specific volumes of its components. Secondly, Kopp finds that isomeric liquids of the same chemical type have identical specific volumes. Thirdly, that in a series of homologues each increment of CH_2 is attended with a constant increment in specific volume. Hence Kopp was able to assign certain fundamental values to a number of elementary bodies, and thus to calculate with a considerable degree of accuracy the specific volume, and hence the specific gravity, of many liquid substances. It also appeared probable that members of the same family of elements have identical specific volumes, or, to use Schröder's expression, are "isosterous." Thus the analogously constituted terchlorides of arsenic and phosphorus appear to possess the same specific volume; whence it follows, since no change is observable in the volume occupied by chlorine in different compounds, that the specific volumes of arsenic and phosphorus are equal. A similar conclusion was drawn with respect to tin and titanium, members of the tetratomic group, from an examination of their tetrachlorides.

It must be admitted, however, that certain of these deductions are drawn from experimental evidence, which, in the light of our present knowledge, can hardly be deemed sufficiently comprehensive to permit of such broad generalizations. For example, the examination of only four liquids can scarcely afford adequate proof of the universality of the statement that members of the same chemical family have identical specific volumes. The conclusion with regard to isomerides was necessarily based on limited proof, for the reason that the number of cases admitting of examination was limited. The number of isomerides has now increased a hundredfold, and we have become more precise in defining their character. The validity of the law should be tested by an examination of well-chosen and typical isomerides, especially among the hydrocarbons. Such an examination would not only afford material for solving the primary question, but would incidentally serve to show whether the specific volumes of the component elements, carbon and hydrogen, are respectively invariable, as stated by Kopp, no matter how these elements may be arranged in a compound with respect to each other.

It has been shown by Professor Roscoe that vanadium is a member of the phosphorus group of elements, and that the vanadium trichloride of Berzelius is in reality an oxychloride of the composition $VOCl_3$, corresponding to the phosphoryl trichloride ($POCl_3$). As both these analogously constituted liquids are readily obtained in a state of purity and boil at moderately high temperatures, it seemed desirable to determine their specific volumes with a view of obtaining further evidence on the isosterism of members of the same chemical family. As the result of a series of carefully conducted observations made on preparations of a high degree of purity, we find that the specific volumes of phosphoryl trichloride and vanadyl trichloride are distinctly different, the chloride with the higher molecular weight having the greater specific volume. We have thus been led to reopen the whole subject. Starting with the observations on the question of the specific volumes of members of the same chemical family, we find that the result foreshadowed in the case of phosphorus and vanadium is a general one, viz. that in a series of analogously constituted compounds belonging to the same chemical family, as, for example, the trichlorides of phosphorus, arsenic, and antimony, and the tetrachloride of silicon, titanium, and tin, the specific volume increases with the molecular weight.

We have completed the experimental work connected with the determination of the rates of expansion, boiling-points, and specific gravities, which data (together with the molecular weights) are required to fix the specific volume, of the following liquids:—

Br
ICl
$C_2H_4Br_2$
C_2H_4ICl
$C_2H_4Cl_2$
CH_3CHCl_2
CH_2Cl_2
CH_2Br_2
$CHCl_3$
$CHBr_3$

CCl_4
$CBrCl_3$

$SiCl_4$
$TiCl_4$
$SnCl_4$

$\left.\begin{array}{l}\text{Ethyl Amyl}\\ \text{and Heptane}\end{array}\right\} C_7H_{16}$

PCl_3
$PCl_2C_2H_5O$
PBr_3
$POCl_3$
$POBrCl_2$
$PSCl_3$
$VOCl_3$
AsF_3
$AsCl_3$
$SbCl_3$

The labour of reducing the observations, and more particularly of calculating the empirical formulæ for so large a number of liquids, is necessarily somewhat heavy and tedious; its completion has been unavoidably delayed by the pressure of other duties. The Committee, if reappointed, propose not only to complete the reduction of the present observations (which work is already in progress), but to extend the investigation so as to include a well-defined series of sulphur compounds (a number of which have been already prepared and some partially investigated), with the view of repeating the observations on the relation of the specific volume of sulphur to the manner in which it is held in union. These results will also afford material for discussing Buff's hypothesis, that the specific volume of an element varies with its atom-fixing power. The only hydrocarbons we have hitherto investigated are ethyl amyl and heptane, both C_7H_{16}, concerning which there is proof that, contrary to Kopp's law, their specific volumes are not identical. Should this result be confirmed by the examination of similarly related hydrocarbons, the statement concerning the invariability of the specific volumes of carbon and hydrogen will need modification.

Sixth Report on Earthquakes in Scotland, drawn up by Dr. BRYCE, *F.G.S. The Committee consists of* Dr. BRYCE, *F.R.S.E.*, Sir W. THOMSON, *F.R.S.*, J. BROUGH, G. FORBES, *F.R.S.E.*, D. MILNE-HOLME, *F.R.S.E.*, *and* J. THOMSON.

DURING the year that has elapsed since the last Meeting of the Association the Comrie district has been in a state of entire quiescence, and no earthquake has been reported from any other part of Scotland. Your Committee has thus nothing of general interest to lay before the Meeting this year.

The plea put forward at the last Meeting for an increase of the grant was founded on the necessity felt by the Committee of having additional apparatus set up at Comrie. They desired to have a check of some kind on the indications of the seismometer belonging to the Association, which is placed in the tower of the parish church, as well as additional means of testing both the direction and intensity of the shocks. For this purpose it seemed necessary to have apparatus of a different kind, and to find a locality somewhat distant from the spot where the seismometer now stands. After experimental trial had been made of contrivances of various kinds, the method of upright cylinders (one of those recommended by Mr. Mallet in his paper in the 'Admiralty Manual') was adopted. The difficulty of finding a suitable site and a competent observer, to whom it should be a matter of perfect convenience to visit that site, next presented itself. No suitable apartment in which to set up the cylinders could be found in the village; and the Committee therefore resolved to erect a small building for the special purpose. Their wish being made known to Peter Drummond, Esq., who resides on his own property of Dunearn, about half a mile direct distance from the parish church, and nearer to the supposed earthquake-focus, he most kindly offered a site on the grounds surrounding his house. Here, accordingly, on a spot carefully selected, the building has been erected. It is founded upon a rock, the same slate-rock of which the valley westwards to Loch Earn and the enclosing hills are composed, and in continuity with it; while it is completely sheltered from the agitating influences of all winds; so strongly built, indeed, is it, that, even if the situation were exposed, only a storm of extreme violence could produce any disturbing effect. No one can have access to the building but by Mr. Drummond's permission; and he has most kindly promised that the cylinders shall be his constant care. Your Committee is greatly indebted to Mr. Drummond, not only for this promise (which is all-important for their purpose) and for his so readily offering a site, but also for his liberality in making all the necessary preparations for erecting the building, so that the cost to the Committee has been considerably diminished.

The building is of stone and lime, very substantial, about 10 feet square, and 11 feet high to the top of the roof, ceiled and floored. On the perfectly level floor two narrow smooth planks are placed, one directed N. & S. and the other E. & W. On each of these are placed six cylinders of boxwood, carefully turned on the lathe, at such distances apart on the planks that one cannot strike against another in falling. The floor is levelled up to the planks with dry fine sand, on which the cylinders must rest, without rolling, if they fall. The cylinders are all of the same height, but of different diameters, so that they are of very various degrees of stability. In this way the exact direction of a shock is indicated, and a rough scale of intensity is had. The narrowest cylinder is of so small diameter that it is hoped a very feeble shock will be marked by its fall.

The perfect accessibility of the building for frequent and regular observation, the certain and ready response of the cylinders to any movement of the ground, and the impossibility of the existence of any disturbing cause, will, it is the hope of the Committee, render the results highly satisfactory as regards the intensity and horizontal direction of any earthquake-shocks which may occur in future years. The comparison of these with the indications of the seismometer may lead to more important conclusions than have as yet been obtained from this inquiry.

Seventh Report of the Committee on the Treatment and Utilization of Sewage, reappointed at Belfast, 1874, *and consisting of* RICHARD B. GRANTHAM (Chairman), *C.E., F.G.S.*, Professor A. W. WILLIAMSON, *F.R.S.*, Dr. GILBERT, *F.R.S.*, Professor CORFIELD, *M.A., M.D.*, WILLIAM HOPE, *V.C.*, F. J. BRAMWELL, *C.E., F.R.S.*

DURING the past year, from March 25th, 1874 to March 24th, 1875, the observations at Breton's Farm, near Romford, were carried on by the Committee, though, owing partly to the want of funds at the beginning of the year, and partly to the fact that the notched board by means of which the flow of sewage was gauged had been removed from the trough by order of the Surveyor to the Local Board, the experiments could not be made as complete as they would otherwise have been.

Instead of gauging the sewage applied to the land, as heretofore, by direct observations in the distributing-trough, the quantities used on the farm have been estimated solely by the method hitherto employed to verify the trough gaugings—*i. e.*, the sewage entering the farm during the working hours of the engine is calculated by ordinary gaugings in the main sewer, and may be considered as the "day" sewage; the remainder, or the "night" sewage, is ascertained by the different heights of liquid in the tanks at the time when the engine stops at night and starts next morning. The quantities thus calculated are given in Table I., from which we see that the amount of sewage received on the farm from the town during the year was 482,335 tons, a considerably larger amount than in previous years; this is partly owing to the fact that more houses have been connected with the sewers.

The amount of effluent water added to the sewage and repumped on to the land was 27,295 tons, making 509,630 tons as the amount of diluted sewage received into the tanks; 491 tons of this were run into the river during excessive flows, &c., and thus the total amount applied to the land was 509,139 tons.

Tables IV., V., VI. and VII. correspond with similar tables in previous Reports; but especial attention is directed to the note at the foot of Table VI., or a wrong idea may be given of the amount of crop produced per acre, especially in the case of the Italian rye-grass.

The total produce of the farm for the year was less (by about 200 tons) than that of the previous one, and less also than the average of the three preceding years, and this notwithstanding that the crops of Italian rye-grass were really better and those of Mangold much better than those of the previous year: thus in 1873–74, 18·69 acres produced 1084·94 tons of Italian rye-grass, or 58 tons per acre; while in 1874–75, 13·95 acres produced 869 tons, or 62·3 tons per acre; while as to Mangold, the crops in 1873–74 were 18·3 tons per acre, while in 1874–75 they were no less than 42·8 tons per acre.

The principal reasons for the decrease in the total weight of the crops are:—

I. The increase in the acreage of the cereal crops.

II. The large quantity of land allowed to lie fallow during the winter, and consequently the small quantity of winter greens grown as compared with previous years.

III. The fact that five crops (four of Rape and one of Turnips) were not carried off the land but ploughed in, and that two others (of wheat) partially failed.

From the autumn of 1874 to the end of the cropping year (March 1875), there were 38½ acres of land entirely fallow. In addition, four crops (=10¾ acres) of Rape and one crop (=6¾ acres) of Turnips were ploughed in, and the land, 17½ acres in all, treated as fallow. Finally, 14 acres of grass were ploughed in during March and April, having thus, so far as produce was concerned, been practically fallow land; making a total of 70 *acres, or nearly two thirds of the cultivated area of the farm*, unproductive during the winter months.

On reference to Table VI. it will be seen that the aggregate acreage of all the crops was 130·42 as against 170·66 of the previous year, which further illustrates the above statement; and this quantity is also less than that of the two other years recorded by the Committee. This is owing to the fact that the system of cropping has been changed, since the census of the town given in the Committee's Report for 1872–73 (Fifth Report) showed that many of the houses in the town were not connected and many only partially connected with the town sewer, so that it became necessary to manure a much smaller area with the sewage.

But an examination of the Tables given in the present and two previous Reports, whilst establishing the above facts, also shows that the weight per acre of crops produced, and the amount of nitrogen estimated to be recovered in them, was more in the year under review than in either of the two preceding years; and the improvement in these respects has been progressive during the three years, thus:—

Year.	Aggregate area.	Total produce.	Produce per acre.	Total Nitrogen estimated to be recovered.	Nitrogen recovered per acre.
	acres.	tons.	tons.	lbs.	lbs.
1872–73.	156	1704	10·9	15,704	101
1873–74.	171	2353	13·8	22,766	133
1874–75.	130	2157	16·5	20,166	153

This result is no doubt partly due to the concentration of the sewage on a smaller area, and partly to the increased richness of the soil, which was demonstrated by the analytical results given in the Committee's Fifth Report.

It is necessary to state that the year 1871–72 would, if added, show an apparent exception to this progress, inasmuch as the total amount of produce that year was 2714 tons, an amount that has not been equalled since; but this exception is only an apparent one, and is caused by the fact that there were then no cereals grown on the farm (whereas in the following years they have formed an important part of the produce), and that a much larger area was under cabbages.

And notwithstanding the large total weight of crops that year, the *rate per acre* of produce was less than in 1874–75; whilst the amount of nitrogen reckoned as recovered in the crops was less than in either 1873–74 or 1874–75, as appears from the figures:—

	Aggregate area.	Total produce.	Produce per acre.	Nitrogen estimated to be recovered in crops.	Nitrogen recovered per acre.
	acres.	tons.	tons.	lbs.	lbs.
1871–72....	168	2714	16·2	19,667	117

The areas given in each case are the total areas of all the *crops*, of course including sometimes the same land twice.

The Committee were unable to have samples of sewage and effluent water analyzed regularly every month; but samples were taken three times a week (equal quantities in the case of the sewage, quantities in proportion to the flow in that of the effluent water) and mixed, and a sample of each mixture taken at the end of the month; thus twelve samples of sewage and twelve of effluent water were obtained.

As the samples had been kept so long and had not (in the case of the sewage) been taken in proportion to the flow, it was thought sufficient to mix quantities of the samples of sewage proportionate to the monthly quantities of sewage pumped, and to have a sample of this mixture (for the whole period) analyzed: in the case of the effluent waters it was thought better to mix equal quantities (as the monthly total quantities could not be ascertained), so as to make four samples, one for each three months, and to have them analyzed.

The results of these analyses are given in the following Tables:—

Breton's Farm.

SEWAGE.—From April 1874 to March 1875 (both inclusive).

	In 100,000 parts.
Ammonia	3·32
Total Nitrogen (in solution and suspension)	5·56
Chlorine	13·00
Nitrogen as Nitrates	none.

EFFLUENT WATER.—In 100,000 parts,

	April, May, June.	July, August, September.	October, November, December.	January, February, March.
Ammonia	0·006	0·112	0·004	0·004
Nitrogen as Nitrates	0·78	0·27	0·26	0·56
Nitrogen *not* as Nitrates	0·13	0·15	0·04	0·06
Chlorine	10·35	11·45	11·00	9·80
Total Nitrogen	0·91	0·42	0·30	0·62

It is to be remarked, in the first place, that the result thus obtained for the total nitrogen of the sewage is very near to the average results already obtained; thus in the year 1871–72 the average was 5·529, and in 1872–73 it was 5·151 per 100,000. And as regards the effluent waters, the total nitrogen is below the average in all cases, and the purification, as shown by the smaller amount of nitrogen *not* as nitrates, is more perfect during the last two quarters; this may be due to the consolidation of the earth around the drainage pipes; but the Committee would not now express a decided opinion on this point, as they intend to institute a series of experiments to investigate the changes which go on in sewage and effluent water when kept for some time.

As 509,139 tons of sewage were utilized on the farm, the total amount of nitrogen supplied was (according to the analysis of the mixed sample) 28·38 tons. Last year, from the data obtained from the two previous years, the total amount was taken at 27 tons; but this year an increase was expected from the fact that more houses have been connected with the sewers.

The total amount of nitrogen recovered in the crops is estimated at 20,166 pounds, or 31·8 per cent. of the nitrogen supplied; in former years the percentages estimated were as follows:—

1871–72	41·76 per cent.
1872–73	26·00 ,,
1873–74	37·60 ,,

The amount this year is exactly the mean of the amounts for the last two years.

It should be understood that in these calculations no deduction is made for the amount of nitrogen that there would be in the normal unsewaged produce; in other words, the figures show the relation of the nitrogen in the total produce (not in the increase only) to that estimated to be supplied in the sewage.

The Committee will be able to continue their investigations, owing to the generous liberality of a Member of the Association, and more complete observations are now going on again systematically at Breton's Farm.

TABLE I.—*Breton's Sewage Farm.*

Statement of Weekly quantities of Sewage received on the Farm from the Town of Romford, from March 25, 1874, to March 24, 1875.

No. of weekly return.	Dates (inclusive).	Average noonday temperature.	Rainfall during week.	Sewage delivered on farm.	Average temperature thereof.
		° F.	in.	gallons.	° F.
198.	1874. March 25 to March 29	56	......	1,321,000	54
199.	„ „ 30 „ April 5	51	0·51	2,045,000	53
200.	„ April 6 „ „ 12	......	0·63	2,129,000	
201.	„ „ 13 „ „ 19	......	0·15	1,780,000	
202.	„ „ 20 „ „ 26	......	......	1,934,000	
203.	„ „ 27 „ May 3	......	0·02	1,901,000	
204.	„ May 4 „ „ 10	......	0·07	1,691,000	
205.	„ „ 11 „ „ 17	......	0·12	1,927,000	
206.	„ „ 18 „ „ 24	......	0·38	1,847,000	
207.	„ „ 25 „ „ 31	......	0·09	1,799,000	
208.	„ June 1 „ June 7	......	0·64	1,986,000	
209.	„ „ 8 „ „ 14	......	......	1,699,000	
210.	„ „ 15 „ „ 21	......	0·43	2,085,000	
211.	„ „ 22 „ „ 28	......	0·78	1,882,000	
212.	„ „ 29 „ July 5	......	0·07	1,794,000	
213.	„ July 6 „ „ 12	......	1·84	2,130,000	
214.	„ „ 13 „ „ 19	......	......	2,066,000	
215.	„ „ 20 „ „ 26	......	0·18	2,437,000	
216.	„ „ 27 „ Aug. 2	......	0·42	2,148,000	
217.	„ Aug. 3 „ „ 9	......	0·08	2,109,000	
218.	„ „ 10 „ „ 16	......	0·67	2,094,000	
219.	„ „ 17 „ „ 23	......	0·01	1,992,000	
220.	„ „ 24 „ „ 30	......	0·13	2,013,000	
221.	„ „ 31 „ Sept. 6	......	0·37	2,066,000	
222.	„ Sept. 7 „ „ 13	......	0·31	2,088,000	
223.	„ „ 14 „ „ 20	......	......	2,063,000	
224.	„ „ 21 „ „ 27	......	0·27	2,232,000	
225.	„ „ 28 „ Oct. 4	......	1·65	2,136,000	
226.	„ Oct. 5 „ „ 11	......	0·61	1,977,000	
227.	„ „ 12 „ „ 18	......	1·06	2,034,000	
228.	„ „ 19 „ „ 25	......	0·04	1,767,000	
229.	„ „ 26 „ Nov. 1	......	1·09	1,991,000	
230.	„ Nov. 2 „ „ 8	......	......	1,740,000	
231.	„ „ 9 „ „ 15	......	0·16	1,860,000	
232.	„ „ 16 „ „ 22	......	0·35	2,022,000	
233.	„ „ 23 „ „ 29	......	......	2,232,000	
234.	„ „ 30 „ Dec. 6	......	1·48	2,466,000	
235.	„ Dec. 7 „ „ 13	......	0·87	2,328,000	
236.	„ „ 14 „ „ 20	......	0·19	2,198,000	
237.	„ „ 21 „ „ 27	......	......	1,826,000	
238.	„ „ 28 „ Jan. 3 1875	......	0·82	1,598,000	
239.	1875. Jan. 4 „ „ 10	......	......	2,040,000	
240.	„ „ 11 „ „ 17	......	0·32	2,213,000	
241.	„ „ 18 „ „ 24	......	0·75	2,522,000	
242.	„ „ 25 „ „ 31	......	0·96	2,752,000	
243.	„ Feb. 1 „ Feb. 7	......	0·12	2,512,000	
244.	„ „ 8 „ „ 14	......	0·27	2,494,000	
245.	„ „ 15 „ „ 21	......	0·21	2,255,000	
246.	„ „ 22 „ „ 28	......	0·16	2,323,000	
247.	„ March 1 „ March 7	......	0·38	2,243,000	
248.	„ „ 8 „ „ 14	......	0·04	2,153,000	
249.	„ „ 15 „ „ 21	......	0·09	2,132,000	
250.	„ „ 22 „ „ 24	......	......	971,000	
			19·79		
			Total ..	108,043,000	

Table IV.—*Breton's Sewage-Farm.*

Statement showing Crops grown from March 25, 1874, to March 24, 1875.

Plot.	No. of beds (inclusive).	Acreage.	Crop.	Date when sown or planted.	Date when cut or gathered.	Produce.		Remarks.
						Total.	Per acre.	
A	1 to 29	9·8	Italian rye-grass	June 1873	May to Nov. 1874......	tons. 640·24	tons. 65·3	Eight cuttings. Grass ploughed in April 4, 1875.
B	1 to 6 & 9 & 10	3·85	Carrots	April 1874..............	Nov. 1874	66·61	21·5	
„	....	....	Broccoli........................	July 1874	Sept. to Dec. 1874...	3·30		Planted where the Carrots were scarce.
„	....	....	Cabbage........................	„ „		12·12		
„	....	....	Kohl rabi	„ „		0·75		
„	7, 8	·95	Hardy green plants	April 1874...............	Aug. 1874	5·93	6·2	
„	11 to 16	2·78	Peas	March 1874	July 1874	8·45	3·0	Straw 6·33 tons.
„	17 „ 26	4·54	Cabbage........................	Oct. 1873	June and July 1874 ...	82·90	18·2	
„	7 & 8 & 11 to 16	3·73	Hardy greens	Aug. and Sept. 1874...	Dec. 1874 to Feb. 1875	20·81	5·6	
„	17, 18	·93	Brussels sprouts	July 1874	Nov. 1874 to Feb. 1875	5·10	5·5	
„	19 to 26	3·61	Cabbage-plants	July and Aug. 1874...	Oct. and Nov. 1874 ...	24·60	6·8	One fourth of crop ploughed in.
„	1 „ 26	12·12	Fallow.					
Total B	....	12·12	....	....	....	230·57	19·0	Plot fallow at end of year. Sown with Barley and Italian rye-grass, March 27, 1875.
C	All.	1·97	Cabbage	Oct. 1873	June to Aug. 1874 ...	32·97	16·7	
„	„	1·97	Rape	Sept. 1874	....	......	......	The Rape-seed failed.
„	„	1·97	Oats	March 1875				
Total C	....	1·97	....	....	....	32·97	16·7	Plot in seed (Oats) at end of year.
D	All.	6·93	Mangold	April 1874	Oct. 1874	341·0	49·2	
„	„	6·93	Cabbage........................	Oct. and Nov. 1874 ...	....	......	......	Crop remains March 25, 1875.
Total D	....	6·93	....	....	....	341·0	49·2	Plot under crop (Cabbage) at end of year.
E	1 to 22	5·76	Wheat	March 1874	Aug. 1874	14·39	2·5	Including 8·53 tons straw.
„	„	5·76	Italian rye-grass	Sept. 1874...............	Nov. „	11·52	2·0	One cutting; grass remains.
Total E	....	5·76	....	....	....	25·91	4·5	Plot under crop (Grass) at end of year.
F	1 to 14	2·97	Wheat	Feb. 1874	Aug. 1874	6·59	2·2	Including 4·34 tons straw.
„	15, 16	·42	Hardy green plants	May 1874	July „	2·42	5·7	
„	17, 18	·42	Savoy plants	„ „	„ „	3·03	7·2	
„	15, 16	·42	Savoys	July „	Nov. and Dec. 1874 ...	5·46	13·0	
„	1 to 14 & 17 & 18	3·39	Cabbage	Oct. „	....	......	......	Crop remains.
„	15, 16	·43	Fallow.					
Total F	....	3·82	....	....	....	17·50	4·6	Part of plot in crop at end of year (Cabbage).

Table IV. (*continued*).

Plot.	No. of beds (inclusive).	Acreage.	Crop.	Date when sown or planted.	Date when cut or gathered.	Produce.		Remarks.
						Total.	Per acre.	
						tons.	tons.	
G	1 to 8 & 11 to 12	2·35	Cabbage	Nov. 1873	June to Aug. 1874	39·33	16·7	
„	13 to 16	·94	Carrots	April 1874	Aug. and Sept. „	9·96	10·6	
„	9	·23	Savoy-plants	„ „	July 1874	1·65	7·2	
„	10 & 17	·47	Broccoli-plants	„ „	Aug. „	3·96	8·4	
„	18 „ 19	·47	Cabbage-plants	„ „	„ „	3·30	7·0	
„	21 „ 22	·47	Brussels sprouts	„ „	July „	3·30	7·0	
„	20	·23	Kohl rabi plants	„ „	Aug. „	3·30	14·3	
„	1 to 22	5·17	Italian rye-grass	Sept. „	....	......	......	Grass remains.
Total G	....	5·17	....	....	....	64·80	12·5	Plot all in grass at end of year.
H	3 to 5	·66	Spinach	April 1874	June 1874	1·50	2·3	
„	8 „ 24	4·86	Cabbage	Oct. and Nov. 1873	May and June 1874	77·04	15·9	
„	1 „ 24	6·40	Italian rye-grass	June 1874	Sept. to Nov. „	35·20	5·5	One cutting; grass remains.
Total H	....	6·40	....	....	....	113·74	17·8	Plot all in grass at end of year.
I	1 to 16	6·09	Wheat	Feb. 1874	Aug. 1874	18·50	3·0	Straw 11·28 tons.
„	17 & 18	·58	Cabbage	Nov. 1873	June & July 1874	11·18	19·3	
„	1 to 18	6·67	Turnips	Sept. 1874	....	......	......	This crop failed.
Total I	....	6·67	....	....	....	29·68	4·5	Plot fallow at end of year.
K	All.	4·44	Mangold	April 1874	Nov. 1874	161·00	36·3	Part of plot fallow at end of year, remainder sown with Spinach.
„	„	·82	Spinach	March 1875.				
Total K	....	4·44	....	....	....	......	......	
L	1	·15	Cabbage	June 1874	Nov. 1874	0·75	5·0	
„	2, 3	·29	Savoys	„ „	„ „	4·28	14·8	
„	4 to 20	2·43	Cabbage	„ „	Sept. to Nov. 1874	16·92	7·0	
„	All.	2·87	Beans	March 1875.				
Total L	....	2·87	....	....	....	21·95	7·7	Plot all sown with Beans at end of year.
M	All.	3·17	Mangold	April 1874	Nov. 1874	121·00	38·2	
„	1 to 12	2·89	Peas	March 1875	....	......	......	Crop remains.
„	13	·28	Fallow.					
Total M	....	3·17	....	....	....	121·00	38·2	Part of plot sown with Peas at end of year.
N	All.	4·15	Italian rye-grass	June 1873	Apr. 1874 to Mar. 1875	229·35	55·3	Grass ploughed in at end of year.

TABLE IV. (*continued*).

Plot.	No. of beds (inclusive).	Acreage.	Crop.	Date when sown or planted.	Date when cut or gathered.	Produce.		Remarks.
						Total.	Per acre.	
						tons.	tons.	
O	All.	5·92	Onions	March 1874	Aug. and Sept. 1874...	55·63	9·4	
"	"	"	Broccoli.....................	June "	" " " ...	6·43	1·1	Planted where Onions were scarce.
Total O	....	5·92	....	....	....	62·06	10·5	Plot fallow at end of year.
P	All.	3·50	Wheat	Feb. 1874	Aug. 1874	5·57	1·6	3·47 tons straw.
"	"	3·50	Rape	Sept. 1874...............	....	......	......	The Rape-seed failed.
"	"	3·50	Oats	March 1875.				
Total P	....	3·50	....	....	....	5·57	1·6	Plot in seed at end of year.
Q	All.	2·34	Wheat	Feb. 1874	Aug. 1874	5·16	2·2	4·04 tons straw.
"	"	2·34	Beans	March 1875.				
Total Q	....	2·34	....	....	....	5·16	2·2	Plot sown with Beans at end of year.
R	Part.	2·40	Wheat	Feb. 1874	Aug. 1874	5·56	2·3	Straw 4·33 tons.
"	"	·12	Oziers	Jan. 1873	Dec. "	·71	5·9	One cutting; Oziers remain.
"	"	2·40	Beans	March 1875.				
Total R	....	2·52	....	....	....	6·27	2·5	Plot nearly all sown with Beans at end of year.
S	All.	·22	Rhubarb	Feb. 1873	April 1874...............	0·45	2·0	Rhubarb remains.
U	All.	2·53	Wheat	Feb. 1874	Aug. 1874	6·75	2·7	4·05 tons straw.
"	"	2·53	Rape	Sept. 1874	....	......	......	The Rape-seed failed.
"	"	2·53	Oats	March 1875.				
Total U	....	2·53	....	....	....	6·75	2·7	Plot fallow till end of year, then sown with Oats.
V	All.	5·93	Wheat	March 1874	Oct. 1874	1·79	0·3	1·15 ton straw. Only one acre of crop ripened.
"	"	5·93	Beans	" 1875.				
Total V	....	5·93	....	....	....	1·79	0·3	Plot all sown with Beans at end of year.
W	All.	2·75	Wheat	March 1874	Aug. 1874	6·58	2·4	4·33 tons straw.
"	"	2·75	Rape	Sept. "	....	......	......	The Rape-seed failed.
"	"	2·75	Peas	March 1875.				
Total W	....	2·75	....	....	....	6·58	2·4	Plot fallow at end of year, then sown with Peas.

TABLE IV.

Plot.	No. of beds (inclusive).	Acreage.	Crop.	Date when sown or planted.
X	All.	3·86	Wheat …………………	March 1874 …………
„	„	3·86	Beans …………………	„ 1875.
Total X	………	3·86	……………	……………
Y	All.	5·60	Hay ……………………	Permanent grass ……
„	„	5·60	Grass-meadow …………	„ „ ……
Total Y	………	5·60	……………	……………

TABLE V.—*Breton's Sewage-Farm.*

Season 1874–75.—Summary of Cropping Return.

Plot.	Acreage.	Crops.	Produce.	
			Total.	Per acre.
			tons.	tons.
A	*9·80	Italian rye-grass	640·24	65·3
B	12·12	Carrots, broccoli, cabbage, kohl rabi, hardy greens, peas, and Brussels sprouts.	230·57	19·0
C	1·97	Cabbage	32·97	16·7
D	6·93	Mangold	341·00	49·2
E	5·76	Wheat and Italian rye-grass	25·91	4·5
F	3·82	Wheat, hardy greens, and savoys	17·50	4·6
G	5·17	Cabbage, carrots, savoys, broccoli, Brussels sprouts, and kohl rabi	64·80	12·5
H	6·40	Spinach, cabbage, and Italian rye-grass	113·74	17·8
I	6·67	Wheat and cabbage	29·68	4·5
K	4·44	Mangold	161·00	36·3
L	2·87	Cabbage and savoys	21·95	7·7
M	3·17	Mangold	121·00	38·2
N	*4·15	Italian rye-grass	229·35	55·3
O	5·92	Onions and broccoli	62·06	10·5
P	3·50	Wheat	5·57	1·6
Q	2·34	Wheat	5·16	2·2
R	2·52	Wheat and oziers	6·27	2·5
S	0·22	Rhubarb	0·45	2·0
U	2·53	Wheat	6·75	2·7
V	5·93	Wheat	1·79	0·3
W	2·75	Wheat	6·58	2·4
X	3·86	Wheat	1·79	0·5
Y	5·60	Hay and meadow-grass	31·00	5·5
	108·44	Total	2157·13	19·9

* See Note at foot of Table VI.

TABLE VI.—*Breton's Sewage-Farm.*

Summary of Crops gathered from March 25, 1874, to March 24, 1875, showing the quantity of each kind of Produce and Nitrogen contained therein.

Crop.	Total acreage of each description of crop.	Produce of each crop.		Total Nitrogen estimated to be in crops.		
		Total.	Per acre.	Per cent.	Total.	Per acre.
		tons.	tons.		lbs.	lbs.
Italian rye-grass	*26·11	916·31	35·1	0·54	11,084	424
Grass (meadow)	5·60	14·00	2·5	0·54	169	30
Hay		17·00	3·0	2·00	761	136
Oziers	0·12	0·71	5·9			
Cabbage	21·46	301·11	14·0	0·25	1,686	78
Hardy greens	5·10	29·16	5·8	0·25	163	32
Savoys	1·36	14·42	10·6	0·25	81	60
Brussels sprouts	1·40	8·40	6·0	0·25	47	34
Broccoli	2·00	13·69	6·8	0·25	77	38
Spinach	0·66	1·50	2·2	0·25	8	12
Kohl Rabi	0·23	4·05	17·6	0·375	34	148
Peas	2·78	peas 2·12 straw 6·33	0·8 2·3	3·40 0·80	161 113	98
Carrots	4·79	76·57	16·0	0·20	343	72
Mangold	14·54	623·00	42·8	0·25	3,489	240
Onions	5·92	55·63	9·4	0·22	274	46
Wheat	38·13	grain 26·01 straw 46·67	0·7 1·2	1·80 0·60	1,676	44
Rhubarb	0·22	0·45	2·0			
	130·42	2157·13	16·5	......	20,166	155

* This acreage of Italian rye-grass includes not only the 13·95 acres of plots A and N (marked * in Table V.), on which the regular crops for the year's use were grown, but also the 12·16 acres of plots E and H (see Table V.), which were sown according to the usual practice for the following year's use, and from which only a first light cutting was taken.

TABLE VII.—*Breton's Sewage-Farm.*

Statement of Land in crop and Land lying fallow on March 24, 1875.

Plot.	Acreage.	Area in crop.	Area fallow.
		acres.	acres.
A	9·80	9·80	......
B	12·12	......	12·12
C	1·97	1·97	......
D	6·93	6·93	......
E	5·76	5·76	......
F	3·82	3·39	·43
G	5·17	5·17	......
H	6·40	6·40	.....
I	6·67	......	6·67
K	4·44	·82	3·62
L	2·87	2·87	......
M	3·17	2·89	·28
N	4·15	4·15	......
O	5·92	......	5·92
P	3·50	3·50	......
Q	2·34	2·34	......
R	2·52	2·52	......
S	·22	·22	......
U	2·53	2·53	......
V	5·93	5·93	......
W	2·75	2·75	......
X	3·86	3·86	......
Y	5·60	5·60	......
	108·44	79·40	29·04

Comparison.

	In crop.	Fallow.	Total.
	acres.	acres.	acres.
March 24, 1872 ...	40·49	63·39	103·88
" " 1873 ...	87·62*	19·93	107·55
" " 1874 ...	89·09*	19·35	108·44
" " 1875 ...	79·40*	29·04	108·44

* As pointed out last year, the area described as "in crop" comprises most of the spring sowings.

On March 24th, 1873, about 22½ acres.
" " " 1874 " 38 "
" " " 1875 " 32 "

Moreover, on the last date there were 14 acres of grass which was immediately after ploughed in. Practically, therefore, in considering the above comparison, 46 acres should be deducted from the area "in crop" March 24, 1875.

Fifth Note on the Dry Earth System.

Dr. Gilbert has, in continuation of the series of results recorded in former Reports, furnished the Committee with the determination of the nitrogen (by the soda-lime process) in soil which has now passed through a Moule's earth-closet six times. The results of the series are as follows:—

	Before used.	After using once.	After using twice.	After using three times.	After using four times.	After using five times.	After using six times.
Percentage of nitrogen in soil dried at 100° C.	0·073	0·240	0·383	0·446	0·540	0·614	0·716

The *increase* in the percentage of nitrogen (determinable by the soda-lime method) was therefore, by each use, as follows:—

	After using once.	After using twice.	After using three times.	After using four times	After using five times.	After using six times.
Increase in the percentage of nitrogen in soil dried at 100° C.	0·167	0·143	0·063	0·094	0·074	0·102

The gain of nitrogen so indicated was therefore greater by the sixth than by any previous use of the soil since the first and second. The average gain was, however, only 0·11 per cent. by each use.

As last year, so again this, Dr. Russell has determined the amount of nitrogen existing as nitrates in the soil. Last year, after the soil had been passed through the closet five times, the amount of nitrogen as nitrates was found to be 0·20 per cent. on the soil calculated as fully dried; and now, after passing through six times, it is found to be 0·254.

The additional results now recorded do not in any way disturb the conclusions previously arrived at by the Committee as to the value of the manure obtained from an earth-closet. For this, and for their opinion of the system in its other aspects, they would refer to their former Reports (III. pp. 187 & 188, IV. p. 143, V. pp. 413 & 439, VI. pp. 213 & 214).

Report of the Committee, consisting of Major WILSON, *R.E., and* Mr. RAVENSTEIN, *appointed for the purpose of furthering the Palestine Explorations.*

THE sum of £100, granted at the last Meeting of the British Association for the purpose of furthering the Palestine Explorations, was paid over by Major Wilson to the Palestine Exploration Fund, with a request that the wishes of the General Committee of the Association, as expressed in their Resolution, might be carried out.

No complete account of the work of the last twelve months has yet been received from Lieut. Conder, R.E., the officer in charge of the Survey; but from his monthly reports to the Committee of the Fund, it would appear that, since the grant of £100 was made, the triangulation of Palestine has been carried southwards as far as Beersheba, and that a large tract of interesting country, including the plain of Philistia and the southern slopes of the mountains of Judah, has been surveyed and plotted on a scale of one inch to a mile.

Amongst other results have been the recovery of several ancient sites, and the corrections of many errors in the topography of Southern Palestine.

Lieuts. Conder and Kitchener, R.E., were recently engaged in running a line of levels from the Mediterranean to the Sea of Galilee; but this work was unfortunately stopped by the attack made upon Lieut. Conder and his party by the people of Safed.

Lieut. Conder, who was badly wounded, has been unable to send a full report on the levelling; but in a letter written shortly before the affray he mentioned that more than ten miles, or about one third of the levelling, had been completed, and gave some details of the manner in which the work was being carried out. The line of levels was being run by two independent observers (non-commissioned officers from the Ordnance Survey); bench-marks were being cut at frequent intervals, and their position fixed by a line of traverse survey from the Mediterranean to the Sea of Galilee, which will be laid down on the one-inch survey.

Lieut.-Gen. Sir Henry James, the Director-General of the Ordnance Survey, was kind enough to lend instruments for the work, and he has taken much interest in its progress.

In consequence of the attack on the Survey party and the spread of cholera, it has been decided to withdraw Lieut. Conder and his staff from Palestine for the present; but as soon as the Survey is recommenced the levelling will be completed.

Third Report of the Committee, consisting of Professor HARKNESS, Prof. PRESTWICH, Prof. HUGHES, Rev. H. W. CROSSKEY, Prof. W. BOYD DAWKINS, Messrs. C. J. WOODWARD, GEORGE MAW, L. C. MIALL, G. H. MORTON, *and* J. E. LEE, *appointed for the purpose of recording the position, height above the sea, lithological characters, size, and origin of the more important of the Erratic Blocks of England and Wales, reporting other matters of interest connected with the same, and taking measures for their preservation. Drawn up by the* Rev. H. W. CROSSKEY, *Secretary.*

THE Committee have received many valuable contributions regarding the occurrence and distribution of Erratic Boulders. The inquiry is not yet sufficiently exhaustive in its details to permit of any generalization; and the Committee find it necessary to continue their record without attempting as yet to connect the facts they report with theories of the history of the glacial epoch.

It will be observed, however, (1) that our knowledge of the extent of country over which erratic blocks are distributed is considerably increased; (2) that the erratic blocks are connected together more clearly in definite groups, distinctly pointing to special centres of distribution; (3) that the grouping and distribution of the blocks are throwing light upon the periods into which the glacial epoch must be divided.

DEVONSHIRE.

Mr. W. Pengelly, F.R.S., F.G.S., reports the following particulars regarding boulders and scratched stones in South Devonshire.

1. *The New Red Sandstone boulders of Waddeton.*

These occur on the left bank of the river Dart, from 3 to 4 miles north of Dartmouth, on the estate of Mr. Studdy. Between the Dart and Waddeton Court, and within sight of the latter, three subangular masses are imbedded in the soil. So far as it is visible, the largest measures 6 feet by 3 feet, and the others are not much smaller.

They occupy the angular points of an isosceles triangle, of which the base, having the direction N. 78° W. to S. 78° E. magnetic, is 30 paces long, whilst the sides are about 50 paces each. In an orchard are numerous pits whence boulders have been dug up from time to time, and one specimen *in situ* measures 3 feet long and 2 broad. In the front garden of a neighbouring farmhouse is an undisturbed boulder. That portion of it which is visible is considerably rounded, and measures 9 feet in mean diameter; its base is also well rounded, and it lodges on undisturbed Devonian slate. This specimen has the appearance of a transported block. Adjacent to the same farmhouse is the site of a boulder which has been broken up and removed by Mr. Studdy, and, from his description, must have been fully 10 feet in mean diameter. On the surface of a boulder projecting from the base of a hedge there are several parallel grooves, crossed by a second set also parallel to one another. This is the only fact suggestive of glacial scratches; but it is not sufficiently pronounced to justify the opinion that the lines were due to such an agency.

These boulders consist of very hard, more or less micaceous red sandstone. All that have been found were imbedded in the soil, and, when dislodged, all that portion of their surfaces which had been protected from the air was very soft and friable, but soon hardened on exposure. So far as has been noted, they all occupy areas having a slate subsoil.

Their heights above mean tide are estimated to be generally from about 70 to nearly 200 feet; but a large specimen has been found not more than from 15 to 20 feet above low water, which appears undisturbed by man.

The boulders being in much request by architects, on account of the hardness and durability of the stone, are sent off to Dartmouth and elsewhere throughout a considerable district.

Besides the sandstone boulders there are two of dolomitized limestone: one of them, between the Dart and Waddeton Court, is rudely globular, and about 2·5 feet in mean diameter; the other is in a field adjacent to that in which there is an old well covered with a red sandstone boulder.

The following questions present themselves respecting the red boulders just described:—1st. Are they travelled masses? 2nd. If so, whence did they come? 3rd. When were they lodged where they now lie? 4th. What was the agent of transportation?

1st. The New Red Sandstone system, as a continuous formation, reached its southern termination in the fine cliff forming the northern boundary of Goodrington Sands, Torbay, about 2 miles in a straight line north-east from Waddeton; but several "outliers" exist to the south and west of that point, and some of them far removed from it—namely, between Goodrington Sands and Saltern Cove, between Saltern Cove and Broad Sands, two very small masses near the top of the cliff between Berry Head and Mudstone Bay, at the village of Slapton on the shore of Start Bay, at Thurlestone in Bigbury Bay, and near Cawsand in Plymouth Sound. If these numerous outliers on all sides of Waddeton be taken as evidence of the denudation of a great volume of New Red rocks in the south and west of Devon (and on this there will probably be little hesitation), it is possible that the blocks under notice may be, not travelled masses, but remnants *in situ* of New Red beds which once covered the older formations now exclusively occupying the district. It is no doubt true that the form they now bear is not inconsistent with transportation; and it is equally true that the waves, which possibly did the work of denudation, may have left them *in situ* and would have reduced them to the shape they now have.

2nd. Neither in the New Red Sandstone cliffs forming almost the entire coast of South-eastern Devon from Torbay to the confines of Dorsetshire, nor in any of the outliers already mentioned, with the exception of the two small masses near Berry Head, is there any sandstone having a hardness at all approaching that of the Waddeton boulders. The blocks, therefore, if they *have* travelled, and if their parent beds *must* be pointed out, certainly connect themselves with the Berry-Head outliers, upwards of 4 miles off as the crow flies, to the exclusion of all other sources, unless, indeed, they are fragments of certain well-known dykes to be briefly described immediately. Boulders similar to those at Waddeton are by no means rare on the Berry-Head plateau; and a large subangular mass of the same material lies at the base of the raised beach between Berry Head and Berry-Head House.

The Devonian Limestone, forming the southern shore of Torbay, is traversed by almost vertical dykes of New Red Sandstone, which form two systems, *one* having a direction which may be conveniently termed east and west, whilst the other runs from north to south. The east and west system is well exposed at intervals from Berry Head to the railway-cutting at the southern end of the viaduct crossing Broad Sands, about 1·5 mile east of Waddeton. This body of limestone extends to Waddeton, where it terminates. It is extensively quarried at Galmpton Creek, on the right bank of the Dart; but there are no traces there of such Red Sandstone dykes as have been already described.

3rd. The fact that the boulders at the Churston station, on the tableland known as Galmpton Common, were completely buried in the soil, may be taken as evidence that a considerable time has elapsed since they were lodged there; and this is borne out by the more or less corresponding condition of most of those at Waddeton. Nevertheless, if man has neither disturbed the specimen mentioned as occupying the very low position in the meadow nor those at higher levels, the general contour of the district can have undergone very little change since they were deposited where they now are, and the date of that event cannot be very remote geologically.

4th. Assuming the boulder formerly adjacent to the farmhouse, and broken up by Mr. Studdy, to have been 10 feet in mean diameter, that its form was spherical or nearly so, and that its specific gravity was 2·5, or not above that of common stone, it must have measured upwards of 500 cubic feet and weighed fully 36 tons. It is no doubt possible for such waves as occasionally break on the British coast to move a mass having this volume and weight; but it may be safely concluded that they could never have transported it across a submarine valley having a depth at all approaching that of the valleys which now separate Waddeton from any area at present occupied by the New Red Sandstone formation. The very soft and friable character of their surfaces when first dug out of the soil renders it eminently improbable that if they had ever borne glacial scratches they could have retained them, and forbids the attempt to come to any conclusions from the mere absence of such marks.

The different levels at which they are found, the present configuration of the surface of the district, and the great weight of some of them, gives probability to the opinion that the boulders have reached Waddeton from some part of the district lying between Berry Head and Galmpton Common, and that they were transported by ice, although no certain decision can as yet be reached.

2. *The Scratched Stones of Englebourne.*

Mr. Pengelly reports that, under the guidance of Mr. Paige-Brown, he examined these scratched stones.

The stones *in situ* were eight in number, all in that part of Mr. Paige-Brown's property known as "Wise's Englebourne." The first was in "The Meadow," and all the others in a field called "Great Yackland." They are all of fine-grained trap, of close texture, and extremely tough; one of them, which has been broken, displays a schistose fracture, and may be a trap ash. Their heights above mean tide do not differ very much, and are estimated at about 100 feet. The lowest specimen is about 6 feet above the bottom of the valley.

No. 1, near the lower gateway of "The Meadow," measures 2·5 feet in length, 1·5 in greatest breadth, and at least 1 foot in depth. No attempt was made to ascertain to what depth it penetrated the soil. It is angular, the upper surface smooth, with the edges and ridges rounded off, which is not the case with the lateral faces. There are numerous grooves on it, quite distinct but not sharp; and whilst most of them are sensibly parallel, and have the direction S. 40° E. and N. 40° W. magnetic, a few cross them in different directions.

No. 2 (the first we inspected in "Great Yackland") has had a portion broken off recently, but its further destruction was stayed by the proprietor. The remnant is larger than No. 1, and it is much more rounded than that mass. It has on it two sets of parallel grooves, one having the direction of E. 10° N. and W. 10° S. magnetic, whilst those of the second or less numerous set cross them in the direction of the magnetic meridian.

No. 3, not far from No. 2, is subangular, and has numerous grooves, all in the direction N. 20° W. to S. 20° E. magnetic.

No. 4, a short distance from Nos. 2 and 3, has probably been disturbed by man. It has two systems of parallel grooves.

No. 5, near No. 4, has also two systems of parallel grooves.

No. 6, also near No. 4, does not appear to bear any grooves.

No. 7 is some distance south of the group 4, 5, and 6. Its length and breadth are nearly equal; some of its edges are partially rounded, and it has two systems of parallel grooves.

No. 8, near No. 7, has an almost square upper face, and does not appear to be scratched.

Of all the specimens No. 2 is the largest and, undoubtedly, the most interesting; and No. 1 is probably the next in interest. They all rest on a slate subsoil, which crops up in certain places.

That the stones have travelled some distance there cannot be a doubt; for whilst they are detached and trappean, they occupy an area having slate as its subsoil.

That they have not travelled far is highly probable, from the fact that trap occurs *in situ* on almost every side of Englebourne, at distances varying from 3 miles to 2·2 miles, to say nothing of numerous remoter masses. Of those in the immediate neighbourhood, one of the largest, about 1·6 mile north, measures 1·7 mile in length by 3 miles in greatest breadth, and is separated by the little river Harber from a much smaller mass on the west side of that stream.

Their size is so inconsiderable as to leave no room for doubt as to their mobility under the action of waves or violent floods; but to this mode of transport there is the grave objection that, with the exception of No. 2, they are not sufficiently rounded, even though due allowance is made for their hard and tough character.

It appears impossible to account for the grooves otherwise than by supposing them to have been produced by ice-transportation. That the famous granite boulder of Barnstaple Bay was ice-borne was shown in a previous Report. That Bovey Heathfield was, during a very recent geological period, cold enough to be the habitat of the arctic and alpine *Betula nana* is a well-established fact, and the thick accumulation known as the "Head" on Bovey Heathfield is explicable on the glacial rather than on any other hypothesis; and were it not that glacial scratches have never been detected on the lofty tors of Dartmoor, where, if anywhere in Devonshire, they might have been expected, rather than on the low grounds about Englebourne, more certainty would attach to the opinion that these scratched stones are proofs of glacial conditions in South Devon, and that, as such, they contribute largely to the solution of the problem of the New Red Sandstone boulders of Waddeton, from 5 to 6 miles further east.

HERTFORDSHIRE.

Mr. R. P. Greg, F.G.S., reports a group of small boulders in the parish of Westmill, near Buntingford, in the N.E. of Hertfordshire, and 30 miles due north of Greenwich.

About 1 foot and 2½ feet. Several found in same field, some 50 yards or so apart.

Much rounded to subangular, angular, and slightly oblong in general form.

No groovings or striations visible.

Nearest point certainly Derbyshire.

90 to 100 miles distant exactly N.E.

The boulders are composed of ordinary Mountain-limestone.

320 feet above sea; about 70 feet above river Rib.

No others have been noticed in Hertfordshire, except three or four in this one field, which lies in a slope, with east aspect, about 70 feet above the river Rib, which runs here to the south.

The boulders in question were not exposed on the surface, but turned up in draining. Drains 3 feet deep. Soil a clayey loam overlying the chalk, which in these parts is more or less covered with clay and gravel to depths of 6 inches to 30 feet or more.

NOTTINGHAMSHIRE.

The Committee has been favoured with the following report from the Rev. A. Irving, F.G.S., of the High School, Nottingham.

1. The boulder and clay deposits herein referred to are scattered over higher parts of the undulating country of the parishes of Plumtree, Stanton-on-the-Wolds, Kegworth, and Widmerpool, in South Notts. The new line of railway, along which they are exposed at present, may be traced on the map running to the west of Plumtree, then converging towards the turnpike-road from Plumtree to Over Broughton. The line runs for several miles near and almost parallel to this road.

2. The dimensions of the largest boulder measured are 4¼ × 2 × 1 feet. It is of Lias limestone, and near the surface of the ground at the top of the hill through which passes the cutting between Stanton and Plumtree.

The smallest boulders are not bigger than a man's fist.

Quartzite pebbles of all sizes (as if from the Bunter) also abound in the boulder-deposits.

3. Those of the Lias limestone are generally angular or only slightly subangular.

Those of Millstone-grit or Carboniferous limestone are generally rounded very much.

4. The direction of the longest axis of the largest boulder mentioned, and of several others observed in the same section, was very nearly due N. and S.

5. (*a*) The striæ are numerous on certain boulders, but *not* on any very great proportion of them. They are generally several inches in length, and seldom exceed a line in depth.

(*b*) The striæ are very variable with respect to the parts of the boulders striated.

(*c*) The striæ are generally in the direction of the longest axes.

6. (1) The boulders of Lias limestone, which greatly preponderate, are derived, in all probability, from the Liassic strata of the immediate neighbourhood, upon which (as shown in the works of the tunnel at Stanton) the boulders partly lie. (2) The nearest Millstone-grit is found at Castle Donnington and Stanton-by-Dale, in Derbyshire, on opposite sides of the Trent valley; the former place 12 miles south of west, the latter 12 miles north of west from the deposits in which they now occur. (3) The nearest Carboniferous limestone which corresponds precisely with that of the boulders is at Ticknall, in Derbyshire, about 18 miles distant south of west.

8. The height of the group above the sea is about 200 feet.

9. The extent of boulder and clay deposits is at least several square miles, if we include the vast accumulation of drift which caps the tops of all the hills about the district, and is exposed in the road-cuttings as well as on the railway. In the cutting between Plumtree and Stanton the boulders are largest and most numerous, and are mingled with an immense number of quartzite pebbles, the whole being in some places so completely bound together as to be almost conglomeratic. In the tunnel (near Stanton) 70 feet of a true boulder-clay are passed through; but in this the large (Lias) boulders occur less frequently, and the pebbles are more thinly scattered. This tunnel penetrates the hill between Stanton and Bank House (Ord. map). The same kind of clay-deposit (or drift) is cut through by the cutting close to Rowhac Cover and by that near Widmerpool New Inn. This clay is extremely tenacious.

10. Very few of the boulders are found at the surface.

In that which is most characteristically a *boulder*-deposit (between Plumtree and Stanton) the boulders are covered entirely by a later drift-deposit, composed mainly of red marl, as if from the Keuper, mingled with a smaller proportion of Lias clay, and containing a few specimens of rolled *Gryphæa*. Here the boulder-deposit fills up a hollow in the Rhætic beds, the erosion of the strata having gone entirely through the *Avicula-contorta* beds into the blue-grey marls below. At the tunnel and further south the boulder-clay rests upon the Lias.

LEICESTERSHIRE.

Mr. J. Plant reports the following:—

Block of porphyritic granite at Shakerstone, near *Gopsall Park*. 5×4×1½ feet. Height above the sea about 350 feet. No scratches or striæ are at present visible, the block having been greatly worn by human agency. Identical in composition with the porphyritic greenstone of Whitwick, near Colville, at the N.E. end of Charnwood Forest, 7 miles from its present site. At the same village great numbers of blocks of all sizes (granite, syenite, greenstone, basalt) are to be found in the foundations of old houses, wells, and churches.

Numerous Charnwood-Forest boulders, 7 miles due north of *Mt. Sorrel*, at Normanton, on spar.

There is no doubt (as pointed out in a previous Report) that Charnwood Forest was a centre of distribution by ice of blocks of all sizes.

Block of Millstone-grit at Hoby, near Melton, about 3×3×3 feet. This grit is of peculiar composition, and full of large rounded pieces of quartz. It must have come from Durham and Northumberland.

WORCESTERSHIRE.

Bromsgrove district.—Ninety-three boulders have been examined in this district, many of them of considerable size. In addition to a few derived from local rocks, they appear to consist of three varieties of felspathic rock—(1) one variety compact, (2) one with small porphyritic crystals, and (3) one a decided ash. The colour of the rock is dark grey to light grey, sometimes with a greenish tinge, but generally bluish. Evidences abound of a very great destruction of boulders in this district from time immemorial. Many have been buried to get them out of the way, and many broken up for building-purposes. It is impossible, therefore, to generalize upon their distribution; but in the mean time it is very noticeable that no specimens of granite boulders have yet been observed in the Bromsgrove district, although they occur so abundantly around Wolverhampton. The following is a list of the principal boulders in this locality. The Committee are under great obligations to Mr. G. Dipple, of Ford House, for his invaluable assistance.

Compact felstone (C. F. below), 2×2×3 ft., 275 feet above sea, corner of new road near station.

Felstone with quartz, 272 feet above sea, three fragments close to railway bridge.

C. F., 2×2×2 ft., 276 feet above sea, three boulders with fragments near Finstal House.

Felspathic ash (F. A. below), 5×3½×3 ft., 280 feet above sea. Another 100 yards up the E. road, 3×2×1½ ft., with four smaller.

F. A., 3½×3½×1½ ft., Webb's farm.

C. F. (almost hornstone), 2 × 1½ × 1 ft., near Stoke Elm and canal bridge; another (felstone) near Meadow Farm.

F. A. (greenish), 21″ × 14″ × 12″, on road from Hanbury to Stoke, with two fragments of Wenlock limestone.

F. A., 18″ × 15″ × 9″, opposite Stoke church, with others smaller.

F. A. (horny), 5½′ × 4′ × 2′ 4″, 273 feet above sea, at Fringe Green.

Felstone (or ash?), six small, on new road to Bromsgrove, 270 feet above sea.

Felstone (or ash), five small, 292 feet above sea, near police station.

Others similar at corner of Old Station Street, Hobbis's Yard, Chapel Street, Mill Lane, Alcester Road, &c., at heights from 282 to 296 feet.

Felspar porphyrite (F. P. below), 4′ 8″ × 2′ 6″ × 1′ 9″, 410 feet above sea, Dog Lane, Catshill.

F. A., 3′ × 2′ × 1′ 8″, 415 feet above sea, near Canister, with another almost as large.

F. P., 6′ 9″ × 2′ 9″ × 1′ 6″, 585 feet above sea, near Woodrow, at corner of road to Lydgate Ash.

F. P., 8′ 5″ × 4′ × 2′, angular, 700 feet above sea, near Whetty.

Permian breccia, small boulders near Burcott.

Felspathic ash, light grey, 3′ × 2′ × 1½′, 380 feet above sea, at Burcott.

Dolerite (? Rowley rag), 2′ × 1′ 6″ × 1′, 280 feet above sea, corner of Perry Hall, opposite church, subangular; another, half a ton weight, reported as buried near.

F. A., with quartz veins, subangular, 4′ × 2′ × 1′ 3″ and 3′ × 1′ 3″ × 1′ 3″, with a large one, more than half buried, near Halfway House; 100 yards further, near gate, four others:—2′ × 1′ 6″ × 1′ 3″, bluish ash, porphyritic; 2′ 6″ × 1′ 3″ × 1′ 3″, almost hornstone; and two smaller F. A.

F. A., a group of nine, near the cross roads, Woodcote Farm; largest 4′ × 2′ 4″ × (boulder half buried), and 4′ × 3′ 6″ × 1′ 10″, subangular or angular.

F. A. (subangular), 3′ 9″ × 2′ 9″ × 2′ 6″, road into Ran Dan Woods.

Many others are found in walls, and some of great size are reported buried thoughout the district.

Mr. C. J. Watson has pointed out a group of boulders between Northfield and King's Norton. They occur in an excavation immediately above the letter *d* of Northfield on the Ordnance Map. Eleven large and some smaller are found within a radius of 20 yards; and many others are scattered through the fields immediately around and extending towards the railway. They are of felstone and felspathic ash. The specific gravity of one of them was 2·63. The following are the measurements of the largest of the group:—F., 6′ × 4′ × 3′; F., 4′ 6″ × 2′ × 2′; F. A., 2′ × 1′ 6″ × 1′; F. P., 3′ 4″ × 2′ × 1′; F., 6′ × 2′ 6″ × (buried); F., 5′ × 3′ × 2′ 6″; F., 2′ 10″ × 2′ 4″ × 1′ 11″; F., 4′ 4″ × 3′ 6″ × (buried); F., 6′ × 3′ × 2′; F., 2′ 4″ × 1′ 8″ × 1′.

Rev. J. M. L. Aston, Vicar of King's Norton, reports a group of boulders of greenish felstone, some of which are worked into the masonry of the foundation of the church-tower and others imbedded in rubbish. They are subangular, and the exposed surfaces are often rounded. The largest is 6′ × 4′ 6″ × 1′ 6″.

A boulder of compact felstone has been found in Cannon Hill Park, Birmingham, 6′ × 4′ 3″ × 4′, rounded in parts and subangular, and to some extent smoothed and polished. It was dug out of valley-drift in making a lake.

These Worcestershire felspathic boulders are probably from Wales. They are in positions which indicate that they have dropped from floating ice rather than been deposited by land-ice. Signs of land-ice in the Midlands must be looked for in boulder-clays at considerable depths beneath the general drift.

LANCASHIRE.

Mr. Morton reports the following cases of isolated boulders:—

1. Hacking Hey, near Liverpool Exchange, parish of Liverpool.
4 ft. 6 in. × 3 ft. 3 in. × 2 ft.
Rounded or subangular.
It was found in an excavation in the boulder-clay, and has since been placed in front of the Museum, in William Brown Street, half a mile from its original position.
Striated lengthways on one of longest sides.
Striæ on one side only.
Striations parallel with the longer axis.
Composed of felspathic breccia.
Original position in the clay, 30 feet above the sea.
Originally imbedded in the boulder-clay.

2. Kensington, near Liverpool (2 miles), parish of West Derby. Rounded boulder.
5 ft. 6 in. × 4 ft. × 2 ft.
It was found in the boulder-clay close by, and placed close to the rock in its present position.
Greenstone diorite in a decomposed state.
About 200 feet above the sea.
Originally imbedded in the boulder-clay.

3. Leasowe Castle, parish of Wallasey. A long rounded mass.
6 ft. 6 in. × 3 ft. × 3 ft.
It has been drawn up from the shore (which is boulder-clay), and deposited, with two others, in the grounds in front of Leasowe Castle.
Greenstone diorite, a rock of common occurrence in the boulder-clay around Liverpool. It has a strong tendency to exfoliate, and contains the mineral isorine.
It was found several feet below high-water mark.
It was probably imbedded in the boulder-clay, and exposed by denudation.

4. Leasowe Castle, parish of Wallasey. Rounded boulder.
7 ft. × 7 ft. × 3 ft.
It has been drawn up from the shore (which is boulder-clay), and deposited, with two others, in the grounds in front of Leasowe Castle.
Striated on part of the longest sides.
A striated surface, 3 ft. × 7 ft. × 7 ft.
Grey syenite.
It was found several feet below high-water mark.
It was probably imbedded in the boulder-clay, and exposed by denudation.

5. Leasowe Castle, parish of Wallasey. A worn flat mass, subangular.
7 ft. × 7 ft. × 2 ft. 6 in.
It has been drawn up from the shore (which is boulder-clay), and deposited, with two others, in the grounds in front of Leasowe Castle.
A variety of felspathic ash, similar to the boulders which occur in the neighbourhood of Llangollen; but it is a question if it comes from the same region, as they are supposed to have done.
It was found several feet below high-water mark.
It was probably imbedded in the boulder-clay, and exposed by denudation.

YORKSHIRE.

Mr. Gibbins reports, at the N.W. of Bradford, a few whinstone boulders similar to the rocks at Scaw Fell, Cumberland, containing small garnets.

To give completeness to their Report, the Committee propose to catalogue from time to time notices of remarkable erratic blocks which may appear.

The following papers by Mr. D. Mackintosh, F.G.S., contain notices of the positions, dispersion, and derivation of many boulders in the North and West of England and in North Wales:—'Quart. Journ. Geol. Soc.' for Nov. 1867, Terminal Curvature of Slaty Laminæ in W. Somerset; for June 1869, Correlation of the Drifts of N.W. Lancashire &c.; for Nov. 1872, Sea-coast Section of Boulder-clay in Cheshire; for Aug. 1873, The more remarkable Boulders of the N.W. of England &c.; for Dec. 1874, Additional Remarks on Boulders, with a particular reference to those of North Wales. 'Geological Magazine' for Sept. 1867, Railway Geology, from Exeter to Newton Bushell and Moretonhampstead; for Aug. 1870, Dispersion of Shapfell Boulders; for Oct. 1870, Origin of the Drifts &c. of the Lake-district; for Dec. 1870, Dispersion of Criffell Granite &c. over the plain of Cumberland; for July 1871, Drifts of the W. and S. borders of the Lake-district, and the three Great Granitic Dispersions; for Jan. 1872, Age of Floating Ice in North Wales; for Sept. 1872, Glacial Drift of the Central Part of the Lake-district, up to 2800 feet above the sea; for Feb. 1874, Section of Preglacial White Clay and Sand near Mold. 'Proc. of W. Riding Geol. Soc.' for 1870, Drift-deposits of the West Riding of Yorkshire &c.

The perpetual destruction of erratic blocks going on throughout the country renders the Committee anxious to receive further reports. The problems to be solved are of large geological importance, and bear directly upon the extension of the ice-fields and the ocean currents, the elevation and subsidence of the land, and the divisions of the periods in the glacial epoch.

Report of the Rainfall Committee for the year 1874–75. *The Committee consists of* C. BROOKE, *F.R.S., Chairman,* J. F. BATEMAN, *C.E., F.R.S.,* ROGERS FIELD, *C.E.,* J. GLAISHER, *F.R.S.,* T. HAWKSLEY, *C.E.,* The Earl of ROSSE, *F.R.S.,* J. SMYTH, Jun., *C.E.,* C. TOMLINSON, *F.R.S.,* G. J. SYMONS, *Secretary.*

YOUR Committee have taken all the steps in their power to complete the reductional work already in hand, and have succeeded with two exceptions, each of which is only partial. The first, and one which is essential to the completeness of our work and invaluable to all future inquirers, is a list of all observations made in the British Isles from the earliest to the present time. The second is an abstract of about 800 position returns, which will indicate the value to be attached to the different current observations. Both of these works are in a very forward state.

With a view to facilitate reference to our reports, and of placing before the Association an epitome of what we have done, our Secretary has embodied in this Report a *précis* of the rainfall work done by your Committee.

RAINFALL WORK UNDER THE AUSPICES OF THE BRITISH ASSOCIATION.

The first reference to the rainfall work which has now reached so full a development is a short note in the British Association Report, 1861, Sections, page 74, which is as follows:—

> "*On British Rainfall. By* G. J. SYMONS.
>
> "The author directed attention to the very contrary statements current on the question—Is there any secular variation in the amount of British rainfall?
>
> "After quoting several of the most important opinions, he stated that, in the hope of finally settling the question, he had commenced collecting all known rain-registers, and had already tabulated [an aggregate of] more than 6000 years' observations.
>
> "He proceeded to invite criticism on the mode of discussion which he intended to adopt, and also on a proposed method of delineation,—the rainfall in 1860, at 241 stations in Great Britain, being laid down on a large map as a specimen."

In 1862, Mr. Symons submitted a paper giving the monthly fall during 1860–61 at 453 stations, preceded by remarks that unless all gauges were accurate, well placed, and their heights above the ground and above sea-level known, their results were not comparable.

This could only be thoroughly ensured by gauges being visited and tested *in situ* by some competent person.

This paper also contained Tables comparing the mean rainfall of the two years 1860–61 with that of the ten years 1850–59, and a short one comparing that of the above-mentioned ten years with several very long series of years. We reprint this short Table, as it remarkably supports the results subsequently obtained by entirely different methods.

Difference between Mean Rainfall, as obtained from long series of years and from the ten years 1850–59.

Division.	Name of Station.	Period of observation.	Total number of years.	Mean of the whole period.	Mean of ten years, 1850–59.	Difference per cent.
				in.	in.	
II.	Greenwich	1815–61	47	25·42	23·16	−9
V.	St. Thomas, Exeter..	1814–61	48	32·80	31·15	−5
VI.	Orleton, Worcester..	1831–61	31	29·18	28·82	−1
VIII.	Bolton-le-Moors ...	1831–61	31	46·92	44·10	−6
IX.	Halifax	1829–61	33	32·38	30·71	−5
XV.	Rothesay, Bute......	1800–61	62	48·31	45·97	−5

This paper was printed *in extenso* among the Reports.

In 1863 the only paper submitted was a short description of some experimental gauges erected by Colonel Ward at Calne, Wilts; but Mr. Symons was requested to report upon the rainfall of the British Isles during the years 1862 and 1863, and the sum of £20 was placed at his disposal for the purpose of constructing and transmitting rain-gauges to districts where observations were not then made—the gauges to be sent within the British Isles, and the loan to be cancelled should the observations not be satisfactorily made.

In 1864 the Report dealt with the steps taken to secure additional stations, stated whither the gauges purchased out of the grant had been sent, reported the establishment, at the cost and under the personal care of Major Mathew, of an extensive series of stations in the Snowdonian district, as to the rainfall of which hardly any thing was known, and the testing *in situ* of a considerable number of rain-gauges. It concluded with the biannual series of tables of rainfall, viz. those for 1862 and 1863, and remarks thereupon. A grant of £30 for the same purposes as in the previous year was passed.

In 1865 an important Report was drawn up by Mr. Symons; it was divided into five principal sections: (1) what had been done prior to 1860; (2) what has been done since 1860; (3) what remains to be done; (4) a few particulars respecting the rainfall of the last fifty years and the fall in 1864; (5) a list of all stations in the British Isles at which rainfall observations were known to have been made, with details respecting them.

Sections (1) and (5) jointly give a nearly complete history of the rainfall observations made in this country from their commencement in 1677 to 1864, and notes of publications upon the subject. Section (2) explains the steps taken by Mr. Symons to collect and arrange these old observations, to publish current ones, to examine rain-gauges *in situ* and also, before despatch, to secure uniformity in records of rainy days (by the adoption of 0·01 in. of rain as the unit), and to secure tolerably equal geographical distribution for the stations. It also briefly notices the necessity for accurate determinations of the influence of elevation above the ground and of variations in the receiving area, and states that experimental determination of these values was in progress. Also notifies the reestablishment of the mountain rain-gauges in the Western Lake-district and the new series in North Wales.

Section (3) was devoted to *what remains to be done*, and need not be considered at length. Much of what was then (1865) described as necessary has been accomplished, and will therefore be subsequently mentioned; but quite as much remains to be done; *e. g.*, the search for old records at the British Museum has been entirely stopped for several years, and the examination of gauges *in situ* has by no means reached its proper development.

Section (4) gave *a few particulars respecting the rainfall of the last fifty years and the fall in* 1864. This was the first approximation to the determination of the fluctuation of the fall of rain over a large extent of country; but as it was followed by a far more elaborate and rather different investigation, its interest is merely historical and confirmatory. At this (the Birmingham) Meeting (in 1865) it was resolved that Mr. Symons should have the assistance and support of a Committee; and the following were the members originally appointed:—J. Glaisher, F.R.S., Lord Wrottesley, F.R.S., Professor Phillips, F.R.S., Professor Tyndall, F.R.S., Dr. Lee, F.R.S., J. F. Bateman, F.R.S., R. W. Mylne, F.R.S., C. Brooke, F.R.S., G. J. Symons, Secretary.

In 1866 a very long Report was presented by your Committee; the principal subjects may be briefly mentioned. In November 1865 a circular letter was sent to the Editor of nearly every newspaper published in the British Isles, with a request for its insertion in the next issue; the letter gave a brief outline of the necessity for rainfall observations, and invited communications from any persons who possessed old records or were willing to become observers. About 1400 of these circulars were issued, many hundred newspapers reprinted them, so that upwards of a million copies must have been circulated. This produced an enormous influx of letters and material additions, both to the store of old observations and to the list of current observers. The Report contained full details of all the gauges examined *in situ* up to that date, viz. 166; also short notices of a series of inclined and tipping-funnelled rain-gauges erected at Rotherham by Mr. Chrimes, and on river-mists in the Thames valley. But the special feature of the Report, and one which is at present unequalled in this or any other country, is the determination of the fluctuation of the rainfall of England during 140 consecutive years, viz. from 1726 to 1865. As all the original data are given in the Report, it is open to any one to verify the conclusions arrived at. Lastly, the Report contained the usual biannual tables of monthly rainfall.

In the 1867 Report the principal fresh subjects are notes respecting the desirability of establishing fresh stations in the vicinity of the Peak of Derbyshire and in the Eastern Lake-district, of the *percentage of annual rain which falls monthly in different localities*, and on an extensive system for approximately determining the height of rain-gauge stations above sea-level. The Report also contains details respecting the examination of 75 stations visited during the year.

The 1868 Report deals briefly with the results obtained by the inclined experimental gauges at Rotherham, and shows the similarity of monthly curves representing—(1) ratio of rainfall at 25 feet to that at 1 foot; (2) velocity of wind; (3) mean angle from vertical of falling rain. It then notices the removal of the Calne experimental gauges to Strathfield Turgiss. The Report proceeds to embody the results of the discussion of about 40,000 monthly values in order to determine the laws which regulate the monthly percentage of annual rainfall in different districts, and gives tabular statements of the results, and factors for eliminating the disturbing element due to the fact that the influence of elevation above ground varies with the time of year. The usual biannual tables of monthly rainfall are given, also a Table comparing the fall 1860–67 with the average for 1850–59, raised by 5 per cent. in accordance with the Table published in 1862. A valuable paper by Professor Phillips was printed as an Appendix, in which he discussed the quantity of rain falling in the Lake-district.

The 1869 Report contains—(1) a code of rules for observers; (2) a sketch and description of Mr. Symons's first pattern of storm rain-gauge, adapted for the accurate measurement of heavy falls of rain of short duration; (3) an abstract and discussion of the results of the gauges erected, first at Calne and then at Strathfield Turgiss, to determine the influence of size and shape upon the amount of rain indicated by rain-gauges: there were twelve gauges, of which the diameters ranged from 1 to 24 inches; and the final result was that, excluding the gauge 1 inch in diameter, which everywhere collects less *pro rata* than any other, the gauges while at Calne only differed 5·8 per cent., the largest quantity being recorded by those gauges which were most easily managed, viz. those 5, 6, and 8 inches in diameter, and that at Strathfield Turgiss they agreed still more closely, all but the 1-inch and 24-inch agreeing within 1·5 per cent.; (4) the Report also contains the results of the visitation of 54 rain-gauge stations.

In the autumn of 1869 our Secretary visited and examined every rain-gauge station in Cornwall, and also those in the Scilly Isles, and thirty-two of the Devonshire stations, besides personally starting several new ones on Dartmoor.

The 1870 Report deals first with the establishment of thirty new stations provided with instruments by this Association, then proceeds to notice the above-mentioned extensive examination tour, 97 stations being reported upon. This is followed by a brief history of experimental determinations of the decrease of rainfall with height, and a detailed description and thorough analysis of the monthly results obtained at Calne. The Report also contains the biannual tables for 1868–69.

The 1871 Report calls prominent attention to the necessity which exists for systematic inspection of stations. It then gives a specimen of forms which were issued to all observers, requesting particulars of the position and surrounding objects of their gauges. After brief notes upon the establishment of some new stations in North Derbyshire, and upon the results of some experiments with "Isolated level" or "pit" rain-gauges, the Report proceeds to notice the results of the discussion of all British rainfall registers which were absolutely continuous from January 1st, 1860 to December 31st, 1869—(1) with reference to their bearing on the question of the existence or otherwise of secular variation of rainfall in the British Isles, and (2) as data indicative of the distribution of rain over the country.

The 1872 Report explains the steps taken in consequence of the strong representations made to your Committee at Edinburgh respecting the necessity for additional stations in the Highlands, viz. the establishment of ten stations principally on the west coast, through the cooperation of the Secretary of the Scottish Meteorological Society, and of about thirty along the Highland and Dingwall and Skye railways, through the kindness of the Directors of those companies.

It announces the presentation by this Committee to the Scottish Meteorological Society of a set of standard measures for the complete verification of rain-gauges, together with the necessary note-books, the understanding being that the Secretary of that Society shall from time to time communicate to this Committee the results obtained by its employment. It concludes with a discussion of the rainfall of the years 1870–71, and the usual biannual tables.

The 1873 Report calls attention to the existence of many districts where additional stations are necessary, but suggests the postponement of any special effort towards their supply until the revised edition of the list of stations published in the Report of this Association for 1865 is completed. The original list has, mainly in consequence of the development of the work under the auspices of the Committee, become obsolete, as it does not contain more than two thirds of the data now collected. The new list will contain notes of all records known at the date of publication, and will be extremely valuable to future inquirers. The Report proceeds to state the result of the issue of the Position Inquiry forms mentioned in the 1871 Report, upwards of 800 of which elaborate returns were received. Although these returns would never remove the necessity for personal inspection, which all experience, both British and foreign, shows to be essential, yet they are extremely valuable as showing the districts in which that inspection is most needed. The monthly percentage of total annual fall during the decade 1860–69, as based upon more than thirty-eight thousand monthly amounts, is then thoroughly discussed, and the inquiry is supplemented by an analysis of several long registers, viz. seventeen registers which individually extend over 40 years, four which extend over 50 years, and one which exceeds 60 years. Lastly the Report gives the details of the inspection of 63 stations.

The 1874 (and last) Report opens with some remarks upon the completion of the abstracts of the position returns and the difficulty respecting their publication, which arises from their very voluminous nature; it then proceeds to the subject of the examination of gauges *in situ*, and dwells with satisfaction on the number inspected. The progress of the list of stations, which has been upwards of five years in hand, is stated; reference is made to the paucity of stations in Ireland; and then details are given of the inspection by our Secretary of the East-Cumberland mountain gauges, which were presented to this Committee in 1869, and have since been kept in operation at their expense. After mentioning a few minor matters, the Report proceeds to discuss fully the exceptional rainfall of 1872 and its many unprecedented features. The usual biannual tables for 1872–73 are then given, and the Report ends with the results of the examination *in situ* of 77 gauges.

The foregoing outline of the contents of our Reports will give an idea of the very important work which has been accomplished under the supervision of your Committee; but no one could fully realize its amount without going carefully through the various branches of work and considering what each implies. We may be permitted to give one illustration. The last line of the above narrative states that "the Report ends with the results of the examination *in situ* of 77 gauges." Now these stations range from Cumberland to Southampton, from Kent to Devon; they are scattered over thirteen counties; they include such difficultly accessible places as Walshaw Dean, Halifax, Dartmoor Prison, and Mardale Green, Haweswater, and have involved at least 1500 miles of travel in order to inspect them.

We proceed to report what occurred at Belfast in 1874 and the work resulting therefrom. With reference to the engineering paper on the drainage of the Shannon &c., considerable attention was drawn to the small number of rain stations in Ireland, which deficiency we had mentioned in our Report. Eventually, on our reappointment at Belfast, we were instructed to obtain additional stations in Ireland, and a special grant was entrusted to us for the purpose.

Without entering into details respecting the steps which we took to obtain additional stations, it will be sufficient to mention that they were so successful that we received 190 offers of assistance. The acceptance of all these offers would have involved an expenditure far beyond the funds at our disposal; and your Committee were therefore reluctantly compelled to make a careful selection, resulting, however, in the establishment of 66 stations, many of them in localities of extreme importance.

In explanation of the large number which we have been enabled to erect out of our small grant, we are bound to state that several have been erected at the expense of private individuals, that we are largely indebted to Mr. Eason of Dublin, who not only gratuitously transmitted all the gauges from London to Dublin, but also subsequently despatched them by various routes to the destinations directed by our Secretary. We are also indebted to him for 100 copies of a map of Ireland, which has been very useful for working purposes, and generally for much assistance. As to the localities, they will be best appreciated by reference to the map (Plate III.). In order to prevent any dereliction of duty on the part of the observers, we have instructed them to report monthly; and we are glad to say that they are working very satisfactorily. We need hardly state that the organization of this large series of stations involved considerable expense, and occupied much time, as the organization of each station involved several letters. Subsequently all our efforts have been concentrated on the compilation of the revised edition of the list of stations and observations to which we have so often referred. We hoped that it would be completed for the present meeting, and have used every possible exertion to secure that object, so that we might not only show the Association precisely what we have done, but also, if they wish it, terminate with partial completeness our labours in connexion with the Association. Conscious that without accuracy scientific work is useless, we have had every entry extracted in duplicate and every difference rigorously examined; the result, however, is that we are only able to present in its perfect form the list for the first six divisions, which include twenty-seven counties.

The Position returns have all been carefully reduced and analyzed, but the final abstract of them for publication has not yet been prepared. The collection of these returns having been suggested by their eminent member Mr. J. F. Bateman, C.E., F.R.S., your Committee were desirous to consult him respecting the manner in which they could best be utilized, and instructed their Secretary to do so. Unfortunately, however, his severe illness has prevented any steps being taken in the matter.

As, in the opinion of your Committee, it is not desirable that these works should be left in their present incomplete state, they are obliged to ask for reappointment.

In conclusion, looking back over the past fifteen years, we find among the work accomplished the following items:—the number of stations raised from 241 to nearly 2000; the influence of size and shape on the indications of rain-gauges has been experimentally examined, and also the effect of height above ground; the laws which regulate the seasonal distribution of rainfall have been ascertained; the secular variation of annual fall has been approximately determined; a code of rules has been drawn up for observers; nearly 250 stations have been started at the cost of the Association, and 629 stations have been visited and the gauges examined by our Secretary.

We have obtained and supported observations on mountain-tops and other inaccessible places where no observations had been made, in Cumberland, Westmoreland, Wales, and Scotland, and also an extensive series in Ireland. When the works actually in hand are completed, we shall also have furnished an index to all observations hitherto made, and a guide to the value to be attached to the returns from at least a thousand observers.

Your Committee cannot conclude without expressing their hope that, as the system of rain-gauges in Ireland has been established with such remarkable success, the labours of the Committee may be continued.

EXAMINATION OF RAIN-GAUGES (*continued from Brit. Assoc. Rep.* 1874, p. 117).

Reference number.	Date of examination.	COUNTY. Station. *OWNER.* *Observer.*	Construction of gauge.	Maker's name.	Time of reading.	Height of gauge. Above ground. ft. in.	Height of gauge. Above sea-level. feet.	Diameters (that marked M = mean). in.	Equivalents of water. Scale-point. in.	Equivalents of water. Grains.	Error at scale-point specified in previous column. in.	Azimuth and angular elevation of objects above mouth of rain-gauge.	Remarks on position &c.	Reference number.
557.	1874. Aug. 10.	SOMERSET. Literary Institution, Bath. *THE INSTITUTION.* *Mr. Russell.*	VIII.	Anon.	9 a.m.	8 7	75	6·00	·1	710	correct.	....	On thermometer-stand in grounds of Institution; corrected glass has been supplied.	557.
								6·00	·2	1420	+·001			
								6·00	·3	2100	+·006			
								6·00	·4	2780	+·011			
								M 6·000	·5	3450	+·017			
558.	1873. Aug. 19.	WILTSHIRE. Tytherton, Chippenham. *MAJOR GRITTON.* *Major Gritton.*	XII.	Casella	9 a.m.	1 0	157	4·95	·1	490	correct.	N.E. Shrubs, 32°.	On lawn; best position available.	558.
								5·00	·2	970	+·003	N.W. Fir, 28°.		
								4·98	·3	1460	+·003	W. Apple, 44°.		
								5·00	·4	1960	+·002	S.&S.S.E. Trees, 32°		
								M 4·983	·5	2460	correct.	N.N.W. House, 22°		
559.	Aug. 20.	WILTSHIRE. Sunnyside, Trowbridge. *W. J. MANN, ESQ.* *W. J. Mann, Esq.*	XII.	Casella	9 a.m.	1 0	190	4·97	·1	490	+·001	N.N.E. Trees, 25°.	In strawberry-bed, good open position.	559.
								5·00	·2	970	+·004	E.S.E. „ 25°.		
								5·00	·3	1470	+·003			
								5·00	·4	1950	+·006			
								M 4·993	·5	2450	+·004			
560.	Aug. 21.	WILTSHIRE. Alderbury, Salisbury. *REV. R. S. HUTCHINGS.* *Rev. R. S. Hutchings.*	XII.	Casella	9 a.m.	0 8	263	4·96	·1	470	+·004	W.S.W. House, 40°.	....	560.
								4·98	·2	970	+·002	W. Tree, 30°.		
								4·96	·3	1460	+·002	N.E. Trees, 30°.		
								5·00	·4	1970	−·001	E. „ 36°.		
								M 4·975	·5	2476	−·004			
561.	Aug. 22.	WILTSHIRE. Lower Woodford, Salisbury. *H. HINXMAN, ESQ.* *H. Hinxman, Esq.*	III.	Knight	....	1 2	150	4·98	·1	500	−·002	S.S.E. Trees, 38°.	Surrounded by vegetables and not firmly fixed; observer promised that this should be carefully done.	561.
								4·95	·2	1000	−·004	E.N.E. House, 20°.		
								4·98	·3	1495	−·005	E. Tree, 18°.		
								4·98	·4	2000	−·007	W.S.W. Tree, 30°.		
								M 4·973	·5	2500	−·010	S. Trees, 20°.		
562.	Aug. 23.	WILTSHIRE. West Dean, Salisbury. *Rl. V. W. EYRE.* *Mr. J. Moodee.*	XII.	Casella	9 a.m.	1 0	140	4·97	·1	490	−·001	N. Tree, 40°.	....	562.
								5·02	·2	970	+·004	N.E. „ 35°.		
								4·99	·3	1460	+·005	E.N.E. & E. Tree, 25°.		
								5·00	·4	1950	+.006	S.W. Tree, 35°.		
								M 4·995	·5	2460	+·003	N.W. „ 38°.		
563.	Aug. 26.	KENT. Eltham Green (Field). *E. J. C. SMITH, ESQ.* *E. J. C. Smith, Esq.*	III.	Negretti	9 a.m.	1 0	80	4·93	·1	445	+·009	....	In a field, quite clear and open ...	563.
								5·04	·2	950	+·006			
								4·95	·3	1450	+·004			
								4·96	·4	1950	+·002			
								M 4·970	·5	2440	+·002			
564.	Sept. 6.	KENT. Dartford (The Downs). *R. F. JARVIS, ESQ.* *R. F. Jarvis, Esq.*	XII.	Apps	9 a.m.	2 4	162	4·98	·1	450	+·009	N.N.E. House, 25°.	Fixed on lawn, in the stump of a tree.	564.
								5·01	·2	1000	−·002	S.&S.S.E. Trees, 34°		
								5·00	·3	1480	+·001	S.W.&W.S.W. Tr. 30°		
								5·00	·4	1970	+·002	N.W. Trees, 25°.		
								M 4·998	·5	2480	correct.			
565.	1874. Aug. 17.	CUMBERLAND. Scotby, Carlisle. *A. SUTTON, ESQ.* *A. Sutton, Esq.*	VIII.	Marshall	9 a.m.	5 6	140	8·00	·1	1255	−·001	E. Low Trees, 20°.	In garden, quite clear except as noted.	565.
								7·86	·192	2400	−·001			
								7·90	·25	3100	+·001			
								7·93						
								M 7·923						
566.	Aug. 17.	CUMBERLAND. Cemetery, Carlisle. *J. CARTMEL, ESQ.* *Mr. Bell.*	X.	Negretti & Zambra	9 a.m.	0 8	114	7·99	·1	1280	−·001	E. Ther.-stand, 48°	A piece of ground 9 ft. × 13 ft. is surrounded by an iron railing 5 ft. high, within which are all the instruments.	566.
								8·02	·108	1390	−·001	N. Railing, 22°.		
								8·00				W. „ 59°.		
								8·00				S. „ 58°.		
								M 8·002						
567.	Aug. 25.	ANTRIM. Linen Hall, Belfast. *Mr. Maitland.*	II.	Anon.	9 a.m.	4 8	30	11·30	·05	1260	correct.	....	In garden in centre of Linen Hal Buildings; quite clear.	6
								11·26	·1	2520	correct.			
								11·30						
								11·23						
								M 11·273						

EXAMINATION OF RAIN-GAUGES (*continued*).

Reference number.	Date of examination.	COUNTY. Station. *OWNER.* *Observer.*	Construction of gauge.	Maker's name.	Time of reading.	Height of gauge.		Diameters (that marked M = mean).	Equivalents of water.		Error at scale-point specified in previous column.	Azimuth and angular elevation of objects above mouth of rain-gauge.	Remarks on position &c.	Reference number.
						Above ground.	Above sea-level.		Scale-point.	Grains.*				
						ft. in.	feet.	in.	in.		in.			
568.	1874. Aug. 26.	ANTRIM. The Manse, Antrim. *REV. J. H. ORR.* *Rev. J. H. Orr.*	III.	Casella	....	1 2	150	5·00 4·98 5·03 4·98 M 4·998	·1 ·2 ·3	500 980 1490	—·001 —·002 —·001	....	In a field east of the town; very open position.	568.
569.	Aug. 28.	ANTRIM. Queens College, Belfast. *THE COLLEGE.* *W. Taylor.*	IV.	Anon.	9 a.m.	7 0	68	11·20 11·30 11·30 11·28 M 11·270	·05	1260	correct.	....	On the lawn south-west of the College; quite unsheltered.	569.
570.	Aug. 28.	ANTRIM. Antrim Road, Belfast. *THE CORPORATION.* *W. J. Smith, Esq.*	IV.	Anon.	9 a.m.	7 0	144	6·66 6·68 6·72 6·66 M 6·680	2·5 —2·3 2·0 —1·75 1·25—1·0 1·0 —0·5 0·5 —0·0	1870 2210 2320 4520 4540	—·004 +·001 —·004 —·001 —·001	....	Gauge has a very much rounded rim; position good.	570.
571.	Aug. 28.	ANTRIM. Old Park. *W. GIRDWOOD, ESQ.* *Mr. Armstrong.*	XII.	Casella	10 a.m.	4 0	224	4·98 5·03 4·98 5·03 M 5·005	·1 ·194	500 980 broken.	—·001 —·003	....	On a post on the east side of a hedge, and south of the works.	571.
572.	Aug. 29.	DOWN. Milltown, Banbridge. *J. SMYTH, JUN., ESQ., C.E.* *J. Smyth, Jun., Esq., C.E.*	X.	Negretti & Zambra	9 a.m.	0 6	200	8·02 7·97 8·03 7·97 M 7·998	·1 ·2 ·3 ·4 ·5	1270 2550 3780 5120 6350	correct. —·001 +·002 —·004 correct.	N. Acacia, 28°. E. Laurel, 12°. S.E. Ash, 35°. W. Trees, under 20°	On lawn with many trees, but none rising to higher angles than those noted.	572.
573.	Aug. 29.	DOWN. Milltown, Banbridge. *J. SMYTH, JUN., ESQ., C.E.* *J. Smyth, Jun., Esq., C.E.*	VIII.	Anon.	....	40 0	220	10·00 sq. 10·00 9·98 10·00 M 9·995	·1 ·2 ·3 ·4 ·5	2370 4870 7410 9940 12490	+·006 +·006 +·006 +·006 +·005	N. Trees, 15°.	On post 5 ft. above top of roof of laboratory.	573.
574.	Aug. 29.	DOWN. Corbet Reservoir. *BANN RES. COMPANY.* *W. Sprott.*	IV.	Mason, Dublin	....	3 3	234	10·10 sq. 10·16 10·18 10·22 M 10·165	·15 ·27 ·38 ·51 ·63	3000 6000 9000 12000 15000	+·035 +·040 +·043 +·050 +·055	S.E. Tree, 22°.	On north bank of river Bann; open position except as noted.	574.
575.	Aug. 29.	DOWN. Bann Reservoir. *J. SMYTH, JUN., ESQ., C.E.* *Mr. J. Burn.*	I.	Anon.	noon.	0 2	440	8·02 8·00 8·04 8·03 M 8·022	....	....	....	N.E.R.-gauge, 25°.	Quite exposed, but gauge No. 576 rather too near; rod correct, but inner cylinder slightly too large.	575.
576.	Aug. 29.	DOWN. Bann Reservoir. *BANN RES. COMPANY.* *Mr. J. Burn.*	IV.	Mason, Dublin	....	3 3	443	10·12 sq. 10·18 10·11 10·16 M 10·142	·14 ·26 ·38 ·48 ·58	3000 6000 9000 11710 14710	+·024 +·029 +·034 +·030 +·015	....	Close to No. 575.	576.
577.	Aug. 31.	DOWN. Waringstown. *MAJOR WARING.* *Major Waring.*	X.	Negretti & Zambra	9 a.m.	0 5	190	8·00 7·98 8·00 8·00 M 7·995	·1 ·2 ·3 ·4 ·5	1270 2480 3740 5040 6320	correct. +·004 +·005 +·002 +·001	E. Trees, 25°.	On large lawn, very good position.	577.
578.	Aug. 31.	DOWN. Waringstown. *MAJOR WARING.* *Major Waring.*	I.	Bryson	....	0 3	190	3·00 2·98 3·00 3·00 M 2·995	·27—2·01 2·01—3·76 3·76—5·57 5·57—7·34 7·34—9·15	3000 6000 9000 12000 15000	+·05 +·06 +·12 +·08 +·12	....	Close to No. 577; gauge not in use.	578.

EXAMINATION OF RAIN-GAUGES (*continued*).

Reference number.	Date of examination.	COUNTY. Station. *OWNER.* *Observer.*	Construction of gauge.	Maker's name.	Time of reading.	Height of gauge.			Diameters (that marked M = mean).	Equivalents of water.		Error at scale-point specified in previous column.	Azimuth and angular elevation of objects above mouth of rain-gauge.	Remarks on position &c.	Reference number.
						Above ground.		Above sea-level.		Scale-point.	Grains.				
	1874.					ft.	in.	feet.	in.	in.		in.			
579.	Sept. 2.	DUBLIN. Fitzwilliam Square W., Dublin. *DR. J. W. MOORE.* *Dr. J. W. Moore.*	III.	Anon.	9 a.m.	3	6	54	5·00	·1	490	+·001	S.E. Poplar, 56°. E. House, 40°. N. Wall, 10°. W. „ 33°.	In small garden in rear of house; bad position, but no better available.	579.
									5·00	·2	980	+·002			
									5·00	·3	1450	+·007			
									5·00	·4	1960	+·005			
									M 5·000	·5	2470	+·002			
580.	Sept. 2.	WICKLOW. Fassaroe, Bray. *R. BARRINGTON, ESQ.* *R. Barrington, Esq.*	IV.	Yeates	9 a.m.	5	0	....	10·02	·1	2520	correct.	S.E. Firs, 30°. W. Wood, 10°.	In garden; good position, but ground undulating.	580.
									10·00	·2	4970	+·003			
									10·00	·3	7470	+·004			
									10·00	·4	9970	+·005			
									M 10·005	·5	12220	+·015			
581.	Sept. 2.	DUBLIN. Fitzwilliam Square, Dublin. *DR. J. W. MOORE.* *Dr. J. W. Moore.*	XII.	Casella	....	0	10	54	5·00	·1	480	+·005	E. House, 39°. N. Wall, 48°. W. Trees, 38°. S. Wall, 28°.	Close to No. 579.	581.
									5·04	·2	980	+·006			
									5·06	·3	1480	+·007			
									5·08	·4	1980	+·008			
									M 5·045						
582.	Sept. 14.	BERKSHIRE. Wantage. *E. C. DAVEY, ESQ.* *E. C. Davey, Esq.*	XI.	Negretti & Zambra	....	7	5	280	4·96	·1	490	+·002	....	On post in kitchen-garden; all clear.	582.
									5·04	·2	990	+·001			
									5·00	·3	1480	+·002			
									5·04	·4	2000	+·002			
									M 5·010	·5	2460	+·006			
583.	Sept. 14.	BERKSHIRE. Long Wittenham, Abingdon. *REV. J. C. CLUTTERBUCK.* *Rev. J. C. Clutterbuck.*	III.	Braham	....	1	0	170	5·00	·1	475	+·004	S.E. Birch, 57°. S. Elm, 44°. N.W. Tree, 41°.	In kitchen-garden, east of vicarage and church.	583.
									5·00	·2	995	−·002			
									4·94	·3	1500	−·004			
									5·00	·4	1970	correct.			
									M 4·985	·5	2480	−·003			
584.	Sept. 14.	BERKSHIRE. Ock Street, Abingdon. *W. BELCHER, ESQ.* *W. Belcher, Esq.*	XI.	Negretti & Zambra	9 a.m.	1	0	176	5·00	·1	490	+·002	S. Rose-bush, 35°.	Level garden; position good except as noted.	584.
									5·02	·2	980	+·003			
									5·03	·3	1455	+·008			
									4·99	·4	1960	+·006			
									M 5·010	·5	2460	+·006			
585.	Sept. 15.	OXFORD. Magdalen Coll. Laboratory. *MAGDALEN COLLEGE.* *J. Harris, Esq.*	XII.	Casella	....	0	8	192	5·00	·1	495	correct.	S. Elms, 35°.	In the botanical gardens; clear except as noted.	585.
									4·98	·2	980	+·001			
									4·97	·3	1470	+·002			
									5·00	·4	1960	+·003			
									M 4·988	·5	2450	+·003			
586.	Sept. 15.	BUCKINGHAM. Addington Manor, Winslow. *E. HUBBARD, ESQ., M.P.* *Mr. J. Mathison.*	XII.	Casella	9 a.m.	0	9	309	5·02	·1	495	correct.	E. Apple, 41°.	In kitchen-garden, well exposed.	586.
									4·98	·2	990	correct.			
									4·99	·3	1490	−·001			
									4·98	·4	1990	−·002			
									M 4·993	·5	2480	−·002			
587.	Sept. 15.	BUCKINGHAM. Addington Manor, Winslow. *E. HUBBARD, ESQ., M.P.* *Mr. J. Mathison.*	X.	Negretti & Zambra	9 a.m.	0	9	309	8·00	·1	1200	+·005	E. Apple, 41°.	Close to No. 586.	587.
									8·00	·2	2500	+·003			
									8·00	·3	3780	+·002			
									8·00	·4	5050	+·002			
									M 8·000	·5	6310	+·003			
588.	Sept. 15.	BUCKINGHAM. Adstock Fields, Buckingham. *E. HUBBARD, ESQ., M.P.* *Mr. W. Weston.*	XII.	Casella	9 a.m.	0	6	350	5·00	·1	490	+·001	N.W. Trees, 35°. E. House, 20°. S.S.W. Trees, 25°.	On small lawn in front of house; owing to the number of trees, no better position obtainable.	588.
									4·98	·2	990	correct.			
									5·00	·3	1490	−·002			
									4·98	·4	1990	−·003			
									M 4·990	·5	2500	−·006			
589.	Sept. 15.	BUCKINGHAM. School Lane, Buckingham. *MR. W. WALKER.* *Mr. W. Walker.*	X.	Negretti & Zambra	9.30 a.m.	1	10	269	7·99	·1	1255	+·001	W. Tree, 48°. S. House, 40°.	Gauge loosely placed in an old tub, and position not good.	589.
									8·02	·2	2560	−·001			
									8·00	·3	3770	+·003			
									8·01	·4	5050	+·003			
									M 8·005	·5	6300	+·004			

EXAMINATION OF RAIN-GAUGES (*continued*).

Reference number.	Date of examination.	COUNTY. Station. *OWNER.* *Observer.*	Construction of gauge.	Maker's name.	Time of reading.	Height of gauge.		Diameters (that marked M = mean).	Equivalents of water.		Error at scale-point specified in previous column.	Azimuth and angular elevation of objects above mouth of rain-gauge.	Remarks on position &c.	Reference number.
						Above ground.	Above sea-level.		Scale-point.	Grains.				
	1874.					ft. in.	feet.	in.	in.		in.			
590.	Sept. 15.	BUCKINGHAM. Castle Fields, Buckingham. *C. PARROTT, ESQ.* *Mr. J. Richards.*	XII.	Casella	8.30 a.m.	1 6	318	5·00	·1	500	−·001	....	Very good position in rear of house; grounds level.	590.
								5·00	·2	1010	−·004			
								5·00	·3	1490	correct.			
								5·01	·4	2000	−·003			
								M 5·002	·5	2490	−·002			
591.	Sept. 1.	HAMPSHIRE. Park Corner, Heckfield. *J. MARTINEAU, ESQ.* *J. Martineau, Esq.*	III.	Casella	9 a.m.	1 3	257	4·99	·1	500	−·001	S.S.W. Tree, 35°.	In flower-garden; clear except as noted.	591.
								5·00	·2	1000	−·002			
								5·00	·3	1480	+·001			
								5·00		broken.				
								M 4·998						
592.	Sept. 30.	KENT. Culverlands Grove, Tunbridge Wells. *— MILLER, ESQ.* *Mr. Townsend.*	X.	Negretti & Zambra	9 a.m.	0 2	403	7·90	·1	1260	−·001	E. Trees, 27°.	On large lawn sloping to S.W.	592.
								7·98	·2	2530	−·002			
								7·97	·3	3760	correct.			
								7·94	·4	5040	−·002			
								M 7·948	·5	6290	−·002			
593.	Oct. 3.	SUSSEX. Crowboro' Beacon Observatory. *C. L. PRINCE, ESQ.* *C. L. Prince, Esq.*	X.	Casella	9 a.m.	0 7	777	8·00	·1	1300	−·002	....	In meteorological enclosure south of observatory; very open position.	593.
								8·00	·2	2530	+·001			
								7·99	·3	3800	correct.			
								8·00	·4	5010	+·005			
								M 7·998	·5	6310	+·003			
594.	Oct. 12.	SUSSEX. The Steyne, Brighton. *BRIGHTON CORPORATION.* *Dr. Taafe.*	XII.	Rowley	....	....	....	5·00	·1	490	correct.	....	Gauge tested before actual erection; it was to be placed in a place selected by myself in the Steyne gardens with other meteorological apparatus.	594.
								4·95	·2	950	+·006			
								5·02	·3	1440	+·006			
								4·92	·4	1950	+·003			
								M 4·973	·5	2450	correct.			
595.	Oct. 13.	SUSSEX. The Dyke, Poyning. *BRITISH ASSOCIATION.* *Mr. W. Thacker.*	XII.	Casella	9 a.m.	1 3	690	5·00	·1	495	correct.	N. Bushes, 20°.	In garden E. of house; good position.	595.
								4·99	·2	1000	−·002			
								5·01	·3	1480	+·002			
								5·00	·4	2000	−·003			
								M 5·000	·5	2490	−·002			
596.	Oct. 20.	ESSEX. The Gardens, Audley End. *MR. J. BRYAN.* *Mr. J. Bryan.*	XII.	Casella	9 a.m.	1 0	163	5·00	·1	500	−·001	S.S.W. Apple, 33°	In gardens near Mr. Bryan's house; clear except as noted.	596.
								5·02	·2	990	correct.			
								4·98	·3	1480	+·001			
								5·00	·4	1960	+·005			
								M 5·000	·5	2480	correct.			
597.	Oct. 20.	ESSEX. Riverside, Audley End. *MR. J. BRYAN.* *Mr. J. Bryan.*	XII.	Casella	9 a.m. 1st.	1 0	151	5·00	·1	490	+·001	....	Very exposed position on bank of river.	597.
								5·02	·2	970	+·004			
								4·98	·3	1450	+·007			
								5·00	·4	1970	+·003			
								M 5·000	·5	2450	+·006			
598.	Oct. 21.	LEICESTERSHIRE. Town Museum, Leicester. *LEICESTER CORPORATION.* *W. J. Harrison, Esq.*	XII.	Casella	9 a.m.	1 0	238	5·00	·1	495	correct.	....	Open garden in centre of town.	598.
								5·00	·2	950				
								5·00	·3	1470	+·003			
								5·00	·4	1980	+·001			
								M 5·000	·5	2470	+·002			
599.	Oct. 21.	WARWICK. St. Mary's College, Oscott. *THE COLLEGE.* *Rev. S. Whitty.*	XII.	Casella	9 a.m.	0 6	461	4·98	·1	490	+·001	....	Clear position, S.W. of the college.	599.
								4·98	·2	980	+·002			
								5·02	·3	1470	+·003			
								5·00	·4	2000	−·004			
								M 4·995						
600.	Oct. 22.	STAFFORD. The Heath House, Cheadle. *J. C. PHILLIPS, ESQ.* *J. C. Phillips, Esq.*	XII.	Casella	9 a.m.	1 0	647	5·00	·1	498	−·001	S.E. Araucaria, 30° N.W. House, 28°.	On sloping ground, W. of house.	600.
								5·00	·2	975	+·003			
								4·97	·3	1480	+·001			
								5·01	·4	1950	+·006			
								M 4·995	·5	2480	−·001			

EXAMINATION OF RAIN-GAUGES (*continued*).

Reference number.	Date of examination.	COUNTY. Station. *OWNER.* *Observer.*	Construction of gauge.	Maker's name.	Time of reading.	Height of gauge.		Diameters (that marked M=mean).	Equivalents of water.		Error at scale-point specified in previous column.	Azimuth and angular elevation of objects above mouth of rain-gauge.	Remarks on position &c.	Reference number.
						Above ground.	Above sea-level.		Scale-point.	Grains.				
	1874.					ft. in.	feet.	in.	in.		in.			
601.	Oct. 22.	STAFFORD. The Heath House, Cheadle. *J. C. PHILLIPS, ESQ.* *J. C. Phillips, Esq.*	XII.	Casella	9 a.m.	1 0	647	5·00	·1	498	correct.	....	Close to No. 600.	601.
								5·00	·2	975	+·003			
								5·00	·3	1480	+·001			
								5·00	·4	1950	+·006			
								M 5·000	·5	2480	correct.			
602.	Oct. 23.	STAFFORD. Upper Tean Vicarage, Stoke-upon-Trent. *REV. G. T. RYVES.* *Rev. G. T. Ryves.*	XI.	Negretti & Zambra	9 a.m.	1 0	470	5·02	·1	470	+·006	N. Vicarage, 31°.	Clear, except as noted.	602.
								5·02	·2	980	+·003	W. Trees, 24°.		
								5·01	·3	1480	+·003			
								5·00	·4	1950	+·009			
								M 5·012	·5	2450	+·008			
603.	Oct. 28.	YORKSHIRE. Hardrow Vicarage, Hawes. *REV. F. W. STOW.* *Rev. R. Pink.*	XII.*	Casella	9 a.m.	1 0	790	5·00	·1	500	−·001	N. House, 51°.	Too much sheltered by house, but no better position obtainable; quite clear in other directions.	603.
								5·02	·2	1000	−·002			
								4·98	·3	1480	+·002			
								5·01	·4	1980	+·001			
								M 5·002	·5	2480	correct.			
604.	Oct. 28.	YORKSHIRE. Lunds. *REV. F. W. STOW.* *Rev. R. Pink.*	See B.A.R. 1867, p. 467.	Casella	....	....	....	3·02	·2	350	+·004	....	Gauge tested, but station not visited.	604.
								3·01	·4	710	+·003			
								3·00	·6	1070	correct.			
								3·00	·8	1420	+·008			
								M 3·007	1·0	1775	+·010			
605.	Oct. 28.	YORKSHIRE. Hawes Vicarage. *REV. DR. PARKER.* *Rev. Dr. Parker.*	XII.*	Pastorelli	9 a.m.	1 0	806	5·03	....	....	....	S. House, 31°.	Good position; the measuring-glass was very faulty, and a new correct one was supplied.	605.
								5·06						
								5·03						
								5·05						
								M 5·042						
606.	Oct. 30.	LINCOLN. Westgate, Louth. *DR. FAWSSETT.* *Dr. Fawssett.*	XII.	Anon...............	9 a.m.	0 9	100	5·00	·1	480	+·003	W. Tree, 35°.	Good position on lawn; clear except as noted.	606.
								5·00	·2	990	+·001			
								5·01	·3	1500	+·002			
								5·02	·4	1980	+·002			
								M 5·007	·5	2470	+·003			
607.	Oct. 30.	LINCOLN. Gospelgate, Louth. *T. W. WALLIS, ESQ.* *T. W. Wallis, Esq.*	III.	Anon...............	....	6 0	109	3·05	·22	400	+·001	....	Very confined garden in centre of town.	607.
								3·00	·53	1000	−·017			
								3·05						
								3·05						
								M 3·037						
608.	Oct. 30.	LINCOLN. Gospelgate, Louth. *T. W. WALLIS, ESQ.* *T. W. Wallis, Esq.*	III.	Anon...............	....	6 0	109	5·04	·1	500	correct.	W. Houses, 39°.	Close to No. 607.	608.
								5·01	·2	1000	correct.	E. „ 28°.		
								5·02	·3	1500	correct.	N.E. „ 43°.		
								5·02	·4	2000	correct.			
								M 5·022	·5	2500	correct.			
609.	Oct. 31.	LINCOLN. Calcethorpe Manor, Louth. *D. G. BRIGGS, ESQ.* *D. G. Briggs, Esq.*	X.	Anon...............	9 a.m.	0 10	380	7·97	·1	1250	+·001	....	Very open position on large lawn.	609.
								7·98	·2	2550	−·002			
								8·00	·3	3810	−·001			
								8·00	·4	5060	correct.			
								M 7·988	·5	6290	+·003			
610.	Oct. 31.	LINCOLN. Calcethorpe Manor, Louth. *D. G. BRIGGS, ESQ.* *D. G. Briggs, Esq.*	XII.	Anon...............	9 a.m. 1st.	0 10	380	5·01	·1	490	+·002	E. Tree, 19°.	Close to No. 609.	610.
								5·03	·2	980	+·004			
								5·02	·3	1490	+·002			
								5·03	·4	1990	+·002			
								M 5·022	·5	2490	+·002			
611.	Nov. 21.	MIDDLESEX. Colney-Hatch Lane, Muswell Hill. *J. W. SCOTT, ESQ.* *J. W. Scott, Esq.*	XII.	Casella	9 a.m.	0 8	310	5·00	·1	500	−·001	S. Apple, 29°.	In kitchen-garden; good position.	611.
								5·00	·2	1000	−·002	E.N.E. Pear, 30°.		
								5·00	·3	1490	−·003	N.N.W. Plum, 20°		
								5·00	·4	2000	−·003	S.W. Oak, 20°.		
								M 5·000	·5	2470	+·002			

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* This mark denotes that the gauge has a deep Snowdonian rim.

EXAMINATION OF RAIN-GAUGES (*continued*).

Reference number.	Date of examination.	COUNTY. Station. *OWNER.* *Observer.*	Construction of gauge.	Maker's name.	Time of reading.	Height of gauge. Above ground.	Height of gauge. Above sea-level.	Diameters (that marked M=mean).	Equivalents of water. Scale-point.	Equivalents of water. Grains*	Error at scale-point specified in previous column.	Azimuth and angular elevation of objects above mouth of rain-gauge.	Remarks on position &c.	Reference number.
						ft. in.	feet.	in.	in.		in.			
612.	1874. Dec. 17.	WILTSHIRE. Marlborough College. *REV. T. A. PRESTON.* *Rev. T. A. Preston.*	X.	Negretti & Zambra	9 a.m.	0 8	456	8·00	·1	1280	−·001	N.W.&N.E.Chapel,39°	On grass in college grounds, S. of chapel.	612.
								7·99	·2	2560	−·002	S. Mound, 18°.		
								8·01	·3	3820	−·001			
								8·00	·4	5050	+·002			
								M 8·000	·5	6320	+·002			
613.	Dec. 17.	WILTSHIRE. Marlborough College. *REV. T. A. PRESTON.* *Rev. T. A. Preston.*	XII.	Casella …………	9 a.m.	1 0	456	4·99	·1	500	−·001	………………………	Close to No. 612.	613.
								5·00	·2	990	correct.			
								5·00	·3	1490	−·001			
								5·00	·4	1960	+·004			
								M 4·998	·5	2450	+·006			
614.	Dec. 17.	WILTSHIRE. Marlborough College. *REV. T. A. PRESTON.* *Rev. T. A. Preston.*	III.	Ladd ……………	9 a.m.	1 3	456	5·00	·1	485	+·002	N.W.-N.E.Chapel,35°	Near No. 612, but rather further from the chapel.	614.
								5·02	·2	980	+·002			
								4·99	·3	1490	correct.			
								5·00	·4	1975	+·002			
								M 5·002	·5	2470	+·002			
615.	Dec. 19.	CARMARTHEN. Asylum, Carmarthen. *G. J. HEARDER, ESQ., M.D.* *G. J. Hearder, Esq., M.D.*	X.	Negretti & Zambra	9 a.m.	0 6	180	7·98	·1	1260	correct.	………………………	Good gauge in very excellent position.	615.
								8·02	·2	2550	−·001			
								7·84	·3	3790	+·001			
								8·12	·4	5040	+·002			
								M 7·990	·5	6350	−·001			
616.	Dec. 19.	CARMARTHEN. Goal, Carmarthen. *MR. G. STEPHENS.* *Mr. G. Stephens.*	X.	Negretti & Zambra	9 a.m.	0 6	92	8·00	………	………	………	S.W. Trees, 27°.	On a large round tower, the centre of which is occupied by a garden. Position unusual, but, I think, unobjectionable.	616.
								7·94	·2	2590	−·005			
								7·96						
								8·02						
								M 7·980	·5	6350	−·003			
617.	Dec. 21.	GLAMORGAN. Tynant, Radyr. *F. G. EVANS, ESQ.* *F. G. Evans, Esq.*	XII.	Casella …………	9 a.m.	1 0	100	4·98	·1	495	correct.	N.N.W. Laburn., 55°.	Best position available. The laburnum will be cut back; and the observer states that rain usually falls very nearly vertically at Tynant.	617.
								5·01	·2	1000	−·002	N.W.-N.E.House, 40°		
								5·00	·3	1490	−·001			
								5·00	·4	2000	−·004			
								M 4·998	·5	2490	−·003			
618.	Dec. 21.	GLAMORGAN. Crockherbtown, Cardiff. *W. ADAMS, ESQ., C.E.* *W. Adams, Esq., C.E.*	XII.	Casella …………	9 a.m.	1 0	35	4·97	·1	500	−·001	S.W. Tree, 65°.	No better position to be had. Observer did not like to cut tree.	618.
								5·03	·2	990	correct.	S.E. ,, 50°.		
								4·98	·3	1480	+·001	N.E. Wall, 35°.		
								4·99	·4	1980	correct.			
								M 4·993	·5	2490	−·004			
619.	1875. June 14.	HERTFORD. Tyler Street, Hitchin. *W. LUCAS, ESQ.* *Mr. W. Anderson.*	XII.	Apps ……………	9 a.m.	1 3	238	5·00	·1	500	correct.	W. Elm, 33°.	In garden, quite open.	619.
								5·01	·2	995	correct.			
								5·03	·3	1500	−·001			
								5·01	·4	2000	−·001			
								M 5·012	·5	2500	−·002			
620.	July 28.	BEDFORD. Oaklands, Aspley Guise. *E. E. DYMOND, ESQ.* *E. E. Dymond, Esq.*	XII.	Casella …………	9 a.m. 1st.	1 0	433	4·98	·1	490	+·001	N. House, 20°.	On lawn, south of house.	620.
								5·02	·2	990	correct.			
								5·00	·3	1480	+·001			
								5·00	·4	1970	+·003			
								M 5·000	·5	2470	+·002			
621.	July 28.	BEDFORD. Oaklands, Aspley Guise. *E. E. DYMOND, ESQ.* *E. E. Dymond, Esq.*	XII.	Casella …………	9.30 a.m.	1 3	433	5·02	·1	490	+·001	N. House, 26°.	12 ft. N. of No. 620.	621.
								4·98	·2	990	correct.			
								4·99	·3	1480	+·001			
								5·00	·4	1970	+·002			
								M 4·998	·5	2470	+·001			
622.	Aug. 12.	CARDIGAN. Gogerddan, Aberystwith. *SIR PRYSE PRYSE, BART.* *Sir Pryse Pryse, Bart.*	XI.	Negretti & Zambra	………	1 1½	80	5·03	·1	500	−·001	W.S.W. House, 3°	On large lawn in broad valley running E.-W.; quite unsheltered.	622.
								5·00	·2	1010	−·003			
								5·00	·3	1480	+·002			
								5·00	·4	1980	+·002			
								M 5·007	·5	2470	+·003			

EXAMINATION OF RAIN-GAUGES (*continued*).

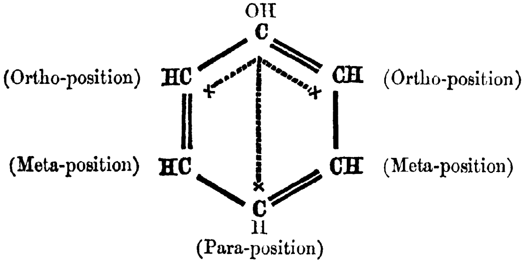
Reference number.	Date of examination.	COUNTY. Station. *OWNER.* *Observer.*	Construction of gauge.	Maker's name.	Time of reading.	Height of gauge. Above ground.	Height of gauge. Above sea-level.
	1875.					ft. in.	feet.
623.	Aug. 12.	CARDIGAN. Great Dark Street, Aberystwith. *MORRIS JONES, ESQ.* *Morris Jones, Esq.*	XII.*	Casella	9 a.m.	1 6	46
624.	Aug. 14.	MERIONETH. Brithdir, Dolgelly. *BRITISH ASSOCIATION.* *J. H. Hill, Esq.*	III.	Casella	9 a.m.	1 0	465
625.	Aug. 14.	MERIONETH. Brithdir, Dolgelly (Field). *J. H. HILL, ESQ.* *J. H. Hill, Esq.*	XII.	Casella	....	....	447
626.	Aug. 14.	MERIONETH. National School, Dolgelly. *MAJOR MATTHEW.* *Mr. Orn Williams.*	III.	Casella	9 a.m.	1 0	43
627.	Aug. 16.	MONTGOMERY. Plas, Machynlleth. *MR. J. JOHNSTONE.* *Mr. J. Johnstone.*	XII.	Apps	....	1 0	47
628.	Aug. 16.	MONTGOMERY. Llanwrin, Machynlleth. *REV. D. EVANS.* *Rev. D. Evans.*	III.	Casella	....	1 0	57
629.	Aug. 16.	MERIONETH. Peniarth. *W. W. E. WYNNE, ESQ.* *The Gardener.*	V.	Anon............	....	1 6	11

Diameters (that marked M = mean).	Equivalents of water. Scale-point.	Equivalents of water. Grains.	Error at scale-point specified in previous column.	Azimuth and angular elevation of objects above mouth of rain-gauge.	Remarks on position &c.	Reference number.
in.	in.		in.			
7·98	·1	1280	−·001	W. House, 36°.	Very bad position; to be removed to an open part of the castle grounds.	623.
8·03				N.W. „ 42°.		
7·98	·3	3790	+·002	N. „ 30°.		
8·02				S. „ 35°.		
M 8·002	·5	6350	correct.			
5·00	·1	490	+·001	....	Clear open position in garden.	624.
4·99	·2	980	+·002			
5·01	·3	1470	+·003			
5·00	·4	1980	+·001			
M 5·000	·5	2470	+·002			
5·00	·1	490	+·001	....	This gauge was not in use. I advised its erection in an adjacent field, rather higher than No. 624.	625.
5·01	·2	980	+·002			
5·00	·3	1470	+·004			
5·01	·4	1980	+·001			
M 5·000	·5	2470	+·002			
5·00	·1	500	−·001	....	Good position in private garden of school.	626.
5·00	·2	980	+·002			
5·00	·3	1480	+·001			
4·99	·4	1980	correct.			
M 4·998	·5	2470	+·001			
5·00	·1	510	−·002	....	In kitchen gardens, S. of the town and unsheltered.	627.
5·03	·2	1020	−·005			
5·01	·3	1500	−·001			
5·01	·4	2010	−·003			
M 5·012	·5	2500	−·002			
4·98	·1	500	−·001	....	Gauge not in use, but site chosen, and its erection promised. Quite clear.	628.
5·02	·2	990	correct.			
5·00	·3	1490	−·001			
5·00	·4	1980	+·001			
M 5·000	·5	2480	correct.			
5·04	·1	530	−·006	....	In gardens, rather too near greenhouse; recommended its removal to an unsheltered site.	629.
4·98	·2	1030	−·006			
5·06	·3	1510	−·003			
4·98	·4	2000	−·001			
M 5·015	·5	2530	−·007			

Report of the Committee, consisting of Dr. H. E. ARMSTRONG *and* Dr. T. E. THORPE, *appointed for the purpose of investigating Isomeric Cresols and their Derivatives. Drawn up by* Dr. ARMSTRONG.

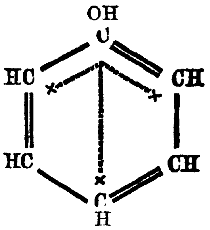
SINCE the last Meeting of the Association a number of derivatives of paracresol have been examined, and some attention has been given to the isomeric cresols; but the investigation has meanwhile assumed a much wider aspect than originally intended, having become a study of the "law of substitution" in the phenol series, for reasons which may be briefly stated as follows.

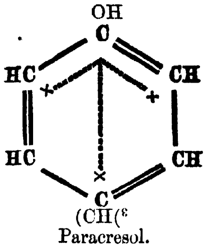
The examination of the derivatives of phenol, C_6H_5OH, carried on during the past four years by various chemists, has shown conclusively that substitution takes place in that compound in a very definite and simple manner. Kekulé's theory, it is well known, admits of the existence of *three* isomeric mono-derivatives of phenol; and it has been found that the action of all reagents which lead to the production of substitution derivatives always gives rise to the simultaneous production of two of the three, the so-called *ortho-* and *para-*derivative. The third isomeric (so-called *meta-*) mono-derivative is seldom formed in any quantity, if at all; thus there is no evidence to show that it is produced in the case of the action of nitric or sulphuric acid, and it is formed only in very small quantity by the action of chlorine and bromine; the action of iodine, however, appears to give rise to a somewhat larger amount of the meta-derivative. The further action of reagents on the ortho- and para-mono-derivatives leads ultimately to the production of *tri-*derivatives, and under ordinary conditions *there is no tendency* to the formation of higher substituted derivatives. In all the di- and tri-derivatives thus directly formed from phenol, it is found that the ortho- and para-positions alone are occupied; so that employing the usual hexagonal symbol to represent phenol, what, in the absence of a better expression, may be termed the direction in which substitution is effected in phenol may be graphically represented, somewhat in the manner suggested by Huebner, by lines drawn within the hexagon, thus:—



It is evidently a problem of considerable importance to determine whether this very simple "law of substitution" obtains in the case of the homologues of phenol; and our experiments have all been instituted in the hope of contributing to its speedy solution. The behaviour of paracresol and of thymol has, to a certain extent, already been studied, and experiments with the isomeric cresols, ethylphenol, xylenol, and carvacrol are in progress.

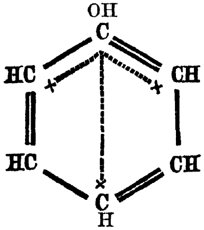
Paracresol derivatives.—Paracresol, $C_6H_4(CH_3)OH$, being formed from phenol by the displacement of the atom of hydrogen in the *para-*position by methyl, it should yield *di-*derivatives only if the "law" above discussed is capable of application, and would accordingly be represented by the symbol:—

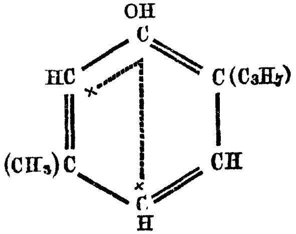

Phenol.


Paracresol.

So far as the action of nitric acid is concerned, it may be said that such is really the case; but the behaviour with bromine does not appear to be in harmony with the "law." Thus paracresol is readily converted into nitroparacresol; and this compound evidently has the nitro-group in the ortho-position, since it is identical with the orthonitroparacresol recently obtained by Wagner from orthonitroparatoluidin. By the further action of nitric acid, orthonitroparacresol is converted into a dinitroparacresol, which, there is every reason to believe, has both nitro-groups in the ortho-positions; it is not possible, however, to introduce a greater number of nitro-groups into paracresol. Similarly, by the action of bromine and iodine on orthonitroparacresol, *monobromo-* and *moniodo-*nitroparacresol only can be obtained. The behaviour of paracresol with bromine has not yet been examined; but the action of bromine on potassium paracresolorthosulphonate, $C_6H_3(CH_3)OH\,SO_3K$, has been studied. From this compound, in the first instance, the corresponding bromoparacresolorthosulphonate, $C_6H_2Br(CH_3)OH\,SO_3K$, is produced; but on further treatment with bromine this is converted into *tri*bromoparacresol, and hitherto no intermediate product has been detected. The tribromoparacresol thus formed has not yet been sufficiently examined to enable an opinion as to its nature to be pronounced; it is a remarkably unstable compound, being decomposed and deprived of a portion of its bromine by mere dissolution in alcohol. This behaviour is certainly remarkable, and may serve on investigation to throw light on the formation of a tri-derivative from paracresol, which at present we are inclined to regard as abnormal. Potassium bromoparacresolorthosulphonate is readily converted by the action of nitric acid into a bromonitrocresol identical with that obtained by treating orthonitroparacresol with bromine.

Thymol derivatives.—Thymol being formed from phenol by the displacement of an atom of hydrogen in the ortho-position by the group propyl, and a second atom in the meta-position by the group methyl, it should "theoretically" furnish only *di*-derivatives, thus:—


Phenol.


Thymol.

The behaviour with bromine is in accordance with this view, inasmuch as we find that thymolparasulphonic acid (formed by treating thymol with SO_3HCl) is converted by the action of bromine into bromothymolparasulphonic acid, which, on further treatment with bromine, is entirely transformed into dibromothymol. It must not be forgotten, however, that Lallemand has prepared such compounds as trichlorothymol and trinitrothymol; and these bodies certainly deserve reinvestigation.

Since meta-derivatives are under certain circumstances produced directly from phenol, it is obvious that the "law" under discussion is not an absolute but merely an approximate expression of experimental observations, the approximation to truth being, however, very close; and the results thus far obtained appear to indicate that in this sense the "law" is equally applicable to the homologues of phenol.

First Report of the Committee for investigating the circulation of the Underground Waters in the New Red Sandstone and Permian Formations of England, and the quantity and character of the water supplied to various towns and districts from these formations. The Committee consisting of Professor HULL, Mr. E. W. BINNEY, Mr. F. J. BRAMWELL, Rev. H. W. CROSSKEY, Professor GREEN, Professor HARKNESS, Mr. HOWELL, Mr. W. MOLYNEUX, Mr. C. MOORE, Mr. G. H. MORTON, Mr. R. W. MYLNE, Mr. PENGELLY, Professor PRESTWICH, Mr. J. PLANT, Mr. J. MELLARD READE, Rev. W. S. SYMONDS, Mr. TYLDEN WRIGHT, Mr. WHITAKER, *and* Mr. C. E. DERANCE (*Reporter*).

YOUR Committee, endeavouring to carry out the investigation with which you have entrusted them, have specially directed their inquiries to obtaining information as to the thickness, character, sequence, and water-bearing properties of the New Red Sandstone and Permian formations, and to the nature and chemical composition of the waters derived from these rocks. As special knowledge and local influence are required in each particular area, your Reporter obtained the consent of the following members of your Committee to undertake the charge of districts:—

In the north-west of England Prof. Harkness, F.R.S., Messrs. Binney, F.R.S., Morton, Mellard Reade, and your Reporter.

In the north-east, Prof. Green and Messrs. Howell and Fox Strangways.

In the Midland counties, Messrs. J. Plant, Molyneux, Tylden Wright, and the Rev. H. W. Crosskey.

In the south-west of England, Messrs. Pengelly, F.R.S., C. Moore, and the Rev. W. S. Symonds.

Through the courtesy of Professor Ramsay, LL.D., F.R.S., Director-General of the Geological Survey of the United Kingdom, and Mr. Bristow, F.R.S., the Director of the English branch, instructions have been given to the officers of the Survey to give your Committee any information or sections they may require. The sections thus obtained from Mr. Clifton Ward are incorporated in the present Report; a large number of others have been promised in the N.E. of England.

The following circular form of inquiry was drawn up and approved by the whole of your Committee, and nearly a thousand copies have been distributed by them. But your Committee regret to report that, owing to the action of certain Corporations and Companies seeking additional Parliamentary powers, information has been withheld from the Committee, as well as by individuals and firms; but your Committee venture to hope that, in the event of their being reappointed, these difficulties may be overcome, and that much additional promised information relating to areas at present reported on will be received.

Name of Member of Committee asking for information ____________

Name of Individual or Company applied to ____________

---

1. *Position* of well or wells with which you are acquainted.

2. Approximate *height* of the same above the mean sea-level.

3. *Depth* from surface to bottom of shaft of well, with diameter. *Depth* from surface to bottom of bore-hole, with diameter.

4. Height at which water stands *before* and *after* pumping. Number of hours elapsing before ordinary level is restored after pumping.

5. *Quantity* capable of being pumped in gallons per day.

6. Does the *water-level* vary at different seasons of the year? and how? Has it diminished during the last 10 years?

7. Is the ordinary *water-level* ever affected by local rains? and if so, in how short a time? And how does it stand in regard to the level of the water in the neighbouring streams or sea?

8. *Analysis* of the water, if any. Does the water possess any marked *peculiarity*?

9. Nature of the rock passed through, including cover of drift, with *thicknesses*.

10. Does the cover of drift over the rock contain *surface-springs*?

11. If so, are they entirely kept *out* of the well?

12. Are any large *faults* known to exist close to the well?

13. Were any *salt springs* or brine-wells passed through in making the well?

14. Are there any *salt springs* in the neighbourhood?

15. Have any wells or borings been discontinued in your neighbourhood, in consequence of the water being more or less *brackish*? If so, if possible, please give section in reply to query No 9.

The following form has been circulated amongst scientific and practical men, to obtain information as to the position of wells and borings.

BRITISH ASSOCIATION FOR THE ADVANCEMENT OF SCIENCE.

UNDERGROUND WATER COMMITTEE.

"Scientific Club, 7 Savile Row,
London, W.
__________187

"Dear Sir,—As it is of great importance to obtain, as far as possible, all the information in reference to wells, borings, and waterworks in, or obtaining their water supplies from, the New Red Sandstone and Permian formations of England, I write to ask you to kindly fill in this sheet with the names and addresses of Individuals, Firms, or Companies likely to afford information, mentioning, under the name, the well or waterworks with which they are connected, and return it to me.

"Should you have yourself sent the circular form of inquiry to any of the names in your list, please put 'S' against them in the *sent column*, and 'R' in the *returned column* to those who have sent you back the form filled up.

"I am, dear Sir,
"Yours faithfully,
"Charles E. De Rance, F.G.S.,
Secretary of the Committee."

No.	Name.	Address.	Sent.	Returned.

Should the Committee be reappointed, it is proposed next year to report on the water-bearing properties of the New Red Sandstone and Permian of the whole of England. 2. The nature and chemical character of the water met with, including the results obtained by the analysis made for the River Pollution Commissioners not yet published. 3. The effect of these waters on the sanitary condition of the people using them. 4. The depth at which these waters occur in various districts where wells are now carried out, and the probable depth at which such waters will occur in districts not yet availing themselves of these waters for a supply.

In the present preliminary Report information from Devonshire, Leicestershire, Lancashire, and parts of other counties are described.

Devonshire.

Torquay.—Dr. Colt, of Maidencombe, describes a well at his house, 250 feet above the level of the sea, which yields a very constant and good supply of water from the Red Sandstone at a depth of 91 feet, the top water being on an average 13 feet 6 inches from the bottom, falling to 9 ft. 6 in. during the dry seasons of 1868, 1869, and 1870, after very severe pumping for the use of neighbours and their cattle.

A fault occurs 300 yards, near which a shaft was sunk 130 feet deep to obtain water, without success.

Teignmouth.—Dr. Lake, writing to Mr. Pengelly, states that a brook rising in the Greensand area of the Haldons, runs through the Combe valley above Teignmouth, a large part of the water being received in a small reservoir for the supply of that town; the remaining portion of the water left in the stream, after flowing down the natural channel, is conveyed in a culvert through the grounds of Myln Villa, after which it flows to the river Teign. During the severe drought of 1870 nearly the entire supply of this stream was taken by the reservoir, and only twenty gallons of water per minute entered the high end of the culvert at Myln Villa; but notwithstanding that, no less than fifty gallons per minute were discharged. Wells were sank to secure more of this excess supply, which was found.

Tiverton.—At Tiverton Mr. H. S. Gill informs Mr. Pengelly that the surface of the water in the wells at the Parish Church and of St. Peter Street is 10 feet below the level of the ground, while at the other end of the street, which is at a slightly lower level, the water has to be pumped up 35 to 40 feet, and of much harder quality than that derived from the shallow wells, which are, however, affected by heavy rains, during which the deeper well-water remains clear and sparkling, especially in a well near the Town Hall, about 270 feet above the sea.

Dawlish.—Dr. Baker informs Mr. Pengelly that the springs are believed to trend with the valley N.N.W. and S.S.E.; breaking at right angles to this line, the wells have to be sunk to a level a little below that of the sea.

A well at Captain Lampen's on the North Hill, 171 feet above the sea-level, was sunk 175 feet through sandstone, gravel, and sand rock, of which 100 feet had to be penetrated before water was found.

In a well (Mr. Turner's) 50 feet lower down the hill, 73 feet deep, the water suddenly disappeared in March 1875; but some water was reached on sinking an additional 5 feet.

In Mr. Marshall's well, recently sunk close to the edge of the cliff, on the opposite side of the valley, at a height of 70 feet above the sea-level, water was reached at 75 feet, beneath a hard pan of red sandstone; when pumped dry, five minutes' rest yields sufficient for thirty minutes more pumping.

At Oaklands, on the S.W. hill, a well is now being sunk at an elevation of 200 feet; a surface-spring was met with at 42 feet, which has been cut off, and the well is now in hard conglomerate at 65 feet.

Near the Station, Hatchers Hotel, and along the railway, an abundant supply of surface-water is found in the gravel at a depth of 14 feet, which supply appears to be pounded back by the sea; these surface-springs vary much in quantity, and are lowest in July. The wells are bricked, and 3 feet 9 inches diameter.

Bramford Speke.—Mr. Gamlen, of Bramford Speke, near Exeter, informs Mr. Pengelly that there are 16 wells in that village, of which 14 are from 45 to 52 feet in depth; the top water of one of these is maintained to a level only 14 feet below the surface of the ground, rising to within 6 feet in winter. The wells are in fine orange-coloured sandstone, overlaid by clean gravel; the bottoms of the wells are below the level of the Exe, but the water is derived from the high ground to the west.

SOMERSETSHIRE.

At *Taunton* Mr. Moore reports the deeper wells 75 feet in depth, situated 100 feet above the sea; Dr. Alford states these are with difficulty pumped dry; the water is derived from the New Red Sandstone, and contains 6 grains per gallon of sulphate and carbonate of lime.

Wells at *Wellington* and *Somerton* yield constant supplies of hard water, unaffected by local rain.

At *Wembdon*, 60 feet above the sea, a well in the Red Sandstone, 30 feet deep, yields a plentiful supply of water, which is also the case at Wells, a well 33 feet deep, at a point 70 feet above the sea.

LEICESTERSHIRE.

The deep wells of *Leicester* reach a maximum depth of 90 feet, and derive their water-supply from the Upper Keuper Sandstone, which dips S.E. at a low angle from the outcrop, or Davies Hill, towards the town and river, which Mr. Plant considers must drain off a large portion of the supply held by the sandstone, which consists of from 20 to 50 feet of sandstone, "separated by beds of stiff red clay varying in thickness from a few inches to six feet." The water in these wells is free from organic impurity; permanent water-level is about the mean height of the water in the river. These wells are tubbed or bricked to keep out surface-springs in the Drift; and one is reported capable of yielding 250,000 to 300,000 gallons a day; another, emptied in 10 hours, was restored to its normal level during the night.

Mr. Plant reports that a number of shallow wells in the town are being gradually closed by the authorities, being under 30 feet in depth, and their supply derived from drift deposits more or less charged with organic impurity.

Mr. Plant states the supply from the New Red Sandstone to be very constant, though limited in quantity, from the smallness of the collecting-area at Davies Hill. The present supply given to the town is from "streams flowing from the Hills of Charnwood Forest, stored in two large reservoirs at Thornton and Cropston."

Mr. Plant sums up the result obtained by him in Leicestershire by stating that the supply of water from the Upper Keuper Sandstone (nowhere more than 50 or 60 feet thick) is small but permanent. All the deep wells of the town of Leicester being supplied from this source, the water is pure but hard from sulphate and carbonate of lime.

In both the eastern and western districts of the county the supply is from the Lower Keuper Sandstone, which is in some places probably 600 feet in thickness. The water is pure but not free from hardness, but the supply is abundant and permanent.

Where the Bunter and Permian beds are penetrated, the supply of water appears to be enormous and entirely unaffected by dry seasons; it is pure and perfectly soft.

These results may be tabulated thus:—

	Formation.	Supply.	Hardness.
1.	Upper Keuper Sandstone.	Not abundant.	Sulph. and carb. of lime.
2.	Lower ,, ,,	Abundant.	Not so hard as 1.
3.	Bunter beds.	More abundant.	Nearly soft.
4.	Permian beds.	Most abundant.	Soft.

The STAFFORDSHIRE returns not being complete, Mr. Molyneux defers sending them until next year; but as previous to this inquiry he had published much information regarding the water-supply of *Burton-on-Trent*, your Reporter has thought it well to briefly allude to his results.

The large number of journals of borings placed at Mr. Molyneux's disposal by Messrs. Allsopp and Sons and Messrs. Salt and Co. have enabled him to establish the following sequences of deposits in the valley of the Trent, near Burton, in descending order:—

1. Old alluvial deposits.	In the bottom of the valley.
2. Valley-sands and gravels.	
3. Terrace-gravels.	On the slope of the valley.
4. Stratified sands, gravels, and peat of fluviatile origin.	
5. Drift sands and gravel.	On the top of the hills.
6. Boulder-clay.	
7. Rhætic beds.	
8. Keuper Marls	1000 feet thick.
9. Keuper Sandstone	250 „
10. Bunter Conglomerate	300 „
11. Coal-measures.	

All the Burton wells previous to 1856 were sunk in the valley-gravels, and were not more than 20 feet deep; in that year Messrs. Ind, Coope, and Co. sank a well 24 feet in depth in Station Street; and since then all the old brewery wells have been deepened, and are now carried down to the underlying Keuper beds.

To obtain a supplementary supply to that afforded by the gravels and the top of the Keuper deposits, Messrs. Bass and Co. bored through 194 feet of gypsum marls with bands of hard sandstone; but it only produced one gallon of water per hour.

In 1867–68 Messrs. Allsopp and Sons sank 28 feet through gravel and bored 102 feet, with a similar unsuccess. The various borings carried out by these firms and Messrs. Salt and Co. prove the existence of two faults in the very centre of the valley, bringing up the Keuper Sandstone, with a vertical downthrow towards the river of no less than 1100 feet, the whole of which enormous mass of strata has been denuded away.

Mr. Molyneux gives the three following analyses—(1) of water from an artesian boring in Keuper marls 70 feet in depth, (2) of water from a well 30 feet deep in valley-gravels, on the east side of High Street, in the time of the old breweries, and (3) of a well on the west side of that street.

	No. 1.	No. 2.	No. 3.
	Grains in an imperial gallon.	Grains per gallon.	Grains per gallon.
Sulphate of lime	70·994	25·480	7·050
Carbonate of lime	9·046	18·060	15·526
Carbonate of magnesia ..	5·880	9·100	2·128
Sulphate of magnesia	12·600	0·000	0·000
Sulphate of soda	13·300	7·630	3·689
Chloride of sodium	9·173	10·010	6·636
Chloride of potassium.. . .	·966	2·275	13·447
Chloride of magnesium ..	·000	0·000	7·350
Carbonate of magnesium..			
Protoxide of iron...........	1·218	·900	Trace
Carbonate of manganese ...	. . .	. ....	Trace
Nitric acid (as lime-salt)..	.. ..	......	Trace
Silica	1·120	·840	1·904
Total solid residues ..	124·297	74·295	57·730

With the exception of the wells in the Keuper Marls at *Hornington*, all the borings prove these marls to be non-water bearing at Burton, the water found coming from the sands beneath them. Mr. Molyneux is therefore of opinion that the large amount of calcareous ingredients found in the artesian wells is derived from the vast area of Keuper Marls with gypseous aggregations occurring in the old area of Needwood Forest, to the west of the valley, the gypsum-charged water flowing along lines of natural underground drainage in a north-easterly direction, until its progress is checked by the great north and south Trent-valley fault, and a portion of the water forced up into the overlying gravels, where it becomes mixed with the ordinary surface-water of the valley, which it charges with the calcareous elements which give it the materials necessary to the production of Burton beer.

Mr. J. P. Griess, F.R.S., informs Mr. Molyneux that the gypsum derived from the water used in brewing 1000 barrels of ale would be 250 pounds; so that, assuming Burton produces annually 1,400,000 barrels of ale, no less than 350,000 pounds of this mineral will be drank with the beer in the various parts of the world. Of the water derived from the Burton valley-gravels, and used in various operations of brewing, probably not less than 1,050,000 pounds of gypsum will be disposed of, which Mr. Molyneux considers will not represent one tenth of the actual amount of gypsum being annually carried to the sea. And it is believed that many local subsidences which have taken place in various parts of Needwood Forest are due to the fracture and sinking of gypsum-beds corroded by underground streams.

The water recently obtained by several of the large brewing firms from the Keuper Sandstone and Bunter beds rose 23 feet above the level of the valley, proving the great height of the sources of supply. These waters were softer than those from the marls or from the valley-gravels, the proportion of sulphate of lime being much less.

LANCASHIRE.

At *Manchester* Mr. Binney has experienced great difficulty in obtaining returns; in fact out of twenty sent out only three have been returned.

In one of these a well and boring at Ayecroft, 433 feet in depth, is stated to produce about 180,000 to 200,000 gallons per day; but the well is only pumped for two or three weeks at a time, chiefly in dry weather.

The well is 70 yards from the river Irwell; and when that river rises, the water in the well rises also.

Prof. Hull states that in 1863 from 60 to 70 wells in the New Red and Lower Permian Sandstones of Manchester and Salford yielded not less than six million gallons per day, used for factories, breweries, bleaching and dye works.

As the collecting-area is only 7 square miles, covered with houses and paved streets, a large part of this supply must be derived from infiltration from the rivers Irk, Medlock, and Irwell.

As the water thus derived is useful for commercial purposes, while that in the rivers is little better than sewage, the great natural filtering-properties of the New Red Sandstone are here remarkably shown.

Dr. R. Angus Smith, F.R.S., found the water from the deep wells of Manchester, in the Permian and Bunter Sandstone, to yield 8 grains of sulphate of lime, and six of carbonate.

Well-water rom the south side of Manchester, analyzed by him in 1865, contained:—

	grains.
Chloride of sodium	4·83
Sulphate of soda	7·33
Carbonate of soda	7·35
„ of lime	9·77
„ of magnesia	5·29
	34·57

The following section of a well and boring at Seedly Print-Works, given by Messrs. Binney and Hull, is of value, as showing that while the Upper Permian series attain a thickness of 128 feet, the Lower Permian Sandstone is but 12 feet 6 inches, though at Collyhurst, 2½ miles to the east, it has expanded to a thickness of 250 feet.

	feet.
1. Drift. Boulder-clay	61
2. Trias. Soft red sandstone	139
3. Upper Permian. Marls, sandstone, and beds of limestone	128
4. Lower Permian. White rock, red sandstone	12½
5. Coal-measures	30
	370½

The whole of the Permian formation, as proved by various wells and borings, is subject to great variation of thickness, due probably to unconformability.

In the borough of *Salford* Mr. Binney has recorded a large number of borings for water at the factories and printing works; one of these, at Messrs. Dewhurst Dawson's Croft, Greengate, gave:—

	feet.
1. *New Red Sandstone.* Red and streaked sandstone	180
2. *Upper Permian.* Red marls, with 4 thin beds of limestone and one of grit	210
3. *Lower Permian.* Soft bright red sandstone, bottom not reached.	

In a boring at the brewery near Albert Bridge, the following sequence occurred:—

	feet.
New Red Sandstone	470
Upper Permian. Red marls with limestone	120
Lower Permian. Red sandstone and clay	10

These borings point to the Lower Permian Sandstone as the source of the water in the deep wells of the Salford district.

At *Ordsall* a boring 460 feet in depth failed to reach the base of the New Red Sandstone, and the water at the bottom of the bore became so salt that the work was given up: this is probably the only instance of salt water being met with in the sandstones of the Trias, though it commonly occurs in the marls.

East of the Manchester coal-field is a tract of New Red Sandstone, 2 miles in width, in which is situated the Gorton Waterworks, where a well 210 feet is capable of yielding 600 gallons per minute, notwithstanding the greater part of the drainage-area is covered with impermeable Boulder-clay.

The New Red Sandstone in the Liverpool and Preston district consists of the following subdivisions:—

	feet.
1. Lower Keuper Sandstone	400
2. The Upper Mottled Sandstone	600
3. Pebble-beds	800
4. Lower Mottled Sandstone	100

Permian beds thin and unimportant.

In a section first described by your Reporter in the railway-cutting at *Orrel*, near Waterloo, the upper beds of the Keuper Sandstone consist of beds of fine-grained sandstone, separated by seams of grey marl, throwing out springs, maintaining the characteristic which gives to the Keuper Sandstone in the Midland counties the name of "waterstones;" between these water-bearing beds and a patch of overlying Keuper Marls let in by a fault a conglomerate bed occurs similar to that occurring at the base of the Keuper. A small well at a private house to the S.W. yields a good supply of water from the water-bearing bed; but it is probable that a large well sank into these rocks would afford a valuable auxiliary supply for Waterloo and Seaforth.

The Upper Mottled Sandstone consists of rather hard yellow sandstone, sometimes used for building, which yields a good supply of water in a well at *Scarisbrick*, of the Southport Waterworks, 70 feet above the sea-level. Nearer Ormskirk are two other shafts sank, by the direction of Mr. Hawksley, in the lower beds of the Upper Mottled Sandstone; in one of these, the Pilot shaft, a good supply of water is obtained; but in the other, a few yards distant, no water was obtained, and the Company are now engaged in driving a heading in hopes of finding some.

At *Ormskirk* Brewery a powerful spring, known as the "Bath Spring," supplies not only the brewery but the town itself. The top of the well is about 134 feet above the level of the sea, is 36 feet in depth, and yields 33 gallons per minute.

The late Mr. Robert Stephenson, reporting on the supply of water to *Liverpool* in 1851, considered the New Red Sandstone of that district, which consists of hard Pebble-beds and Upper Mottled Sandstone, to be generally very pervious, deep wells drawing their supplies from distances of more than a mile; and he appears to have considered the whole mass as nearly equally permeable in every direction, except when fissures or faults filled with argillaceous matter divide the field into water-tight compartments; and he showed that the yield of no well can be permanently increased by sinking, tunnelling, or boring, except so far as the contributing area is thereby enlarged.

The mass of the Liverpool wells draw their supplies from the sandstone at a level between high- and low-water mark; and when the uniform pressure of the column of fresh water, which prevents any ingress of the fluctuating tidal water, is interfered with by excessive pumping, the general top-water level is lowered, and Mr. Stephenson pointed out that a reverse action ensues and the brackish water obtains a slight advantage.

As larger and larger quantities of water are pumped, the current of brackish water gains in head; and it appears to be gradually reaching further and further inland; the wells at Bevington Bush, Soho Square, Hotham Street, and other places have had to be abandoned; but whether it will be able to penetrate the faults which divide the Liverpool area into a series of different water-bearing belts is exceedingly doubtful.

The high permeability of the New Red Sandstone is remarkably shown in the Green-Lane well of the Liverpool Corporation waterworks, of which the details were furnished to Prof. Hull by Mr. Duncan, the resident engineer.

The well was sunk in 1845–46, at a point 144 feet above the sea-level, to a depth of 185 feet, or 41 feet below the sea. The yield was then 1,500,000 gallons per day.

A 6-inch bore, sunk 60 feet from the bottom of the well, increased the yield to 2,317,000 gallons.

In June 1853, the supply having slightly fallen off, the bore-hole was deepened a further 38½ feet, when the yield increased to 2,689,000 gallons.

In June 1856 the bore-hole was widened, and carried a further 101 feet, when the supply rose to 3,321,000 gallons per day.

In the first boring, as pointed out by Prof. Hull, the increase was at the rate of 17,783 gallons per foot, in the second it was only 9789 gallons per foot, and the third only yielded 6277 additional gallons per foot; so that increase of depth gives so rapidly a diminishing ratio of volume, that a zero-point would be soon attained.

The large volume of water in this well is believed to be due to the existence of a large fault, which acts as a duct for the underground waters over a large area.

The water from the Green-Lane well was analyzed in 1850 by Mr. Phillips, and one gallon contained:—

	grains.
Carbonate of lime	5·26
Chloride of sodium	2·66
Sulphate of soda	2·23
Silica	0·64
Organic matter, &c.	2·81
	13·60

Mr. Isaac Roberts, who has given much attention to the wells of Liverpool, found by experiment that one square foot of compact sandstone 10½ inches in thickness, of average coarseness, allowed the following quantities of water to pass through it per hour:—

At a pressure of	10	lbs. to the square inch		4½	gallons.
,, ,,	20	,,	,,	7½	,,
,, ,,	46	,,	,,	19	,,

the increase being nearly directly as the pressure.

Mr. Roberts examined the Liverpool sandstone microscopically, and found it to consist of roughly rounded grains of quartz attached at the points of contact with a siliceous cement. When a block of this sandstone is immersed in water, the grains do not absorb but attract the water into the spaces between the grains by capillary attraction—sandstone of ordinary coarseness taking up no less than $\frac{1}{22}$ of its own weight of water, of which $\frac{1}{10}$ runs away by the influence of gravity, the remainder being held in the cavities of the stone by capillary attraction.

Mr. Roberts describes seven wells which he has sunk or deepened at Liverpool, and gives information concerning them, which clearly proves the gradually lessening amount of rainfall which can make its way into the ground through the large extent of area in Liverpool covered with buildings or streets, which has caused the underground water to no longer flow from the sandstone towards the sea, but to allow a current of tidal water to set in towards the land, which gradually increasing in volume, the water in these wells becomes yearly more and more charged with salts.

A well at (1) Earl Street, 350 yards from the Mersey, was perceptibly affected by the tide, the top water sinking to low-water level at low tide, the bottom of this well being 32 feet below high water.

In a well at (2) Rainford Square, 500 yards from the river, the bottom of which is 76 feet below high-water mark, the supply is abundant; and Mr. E. Davis, F.C.S., found by analysis that it contained

	grains.
Mineral matter per gallon	231·00
Organic matter ,,	1·75
	232·75

The mineral matter consisting of:—

Chloride of calcium.	Sulphate of lime.
,, magnesium.	,, magnesium.
,, potassium.	Carbonate of lime.
,, sodium.	,, magnesia.
Oxide of iron.	Nitrate of ammonia, trace.

The large quantities of salts in this well render it unfit for generating steam, for which it was formerly used.

In the water from a well (3) at Johnson Street, 850 yards from the Mersey, Mr. Phillips, of London, found the following salts per gallon:—

	grains.
Sulphate of lime	8·80
Carbonate of lime	24·33
Chloride of lime	5·05
,, magnesium	20·80
,, sodium	55·79
	114·77

The analysis was made in 1850, up to which time the water was suitable for brewing, but afterwards became so brackish that its use had to be discontinued.

A well in (4) Wellington Street, about 1200 yards from the river, was sunk in the Keuper Sandstone to a depth of 71 feet below high water. An analysis of the water from a neighbouring well, made in 1865, gave 117·70 grains of solid matter per gallon, consisting of:—

	grains.
Sulphate of lime	29·50
Chloride of lime	4·00
,, magnesium	33·60
,, sodium	47·60
Carbonate of lime	2·00
Iron, alumina, &c.	1·00
	117·70

(Analysis made by Messrs. Huson and Audle for Mr. Westworth.)

An analysis of the Corporation well at Bootle, about 1800 yards from the river, made in 1850 by Mr. Phillips, gave 24 grains of solid matter per gallon, consisting of:—

	grains
Sulphate of lime	3·31
Carbonate of lime	7·10
,, magnesia	6·93
Chloride of sodium	3·37
Silica	0·48
Organic matter	2·81
	24·00

Mr. Roberts gives the two following analyses, as showing the source of the increasing salinity of the Liverpool wells to be due to the percolation of the river and not to any natural hardness. Analysis A was made in 1850 by Mr. Phillips, of well-water in Great Howard Street, Liverpool, 200 yards from the docks. Analysis B was made in 1869 by Mr. A Norman Tate, F.C.S., of halftide-water, procured from the Mersey by Mr. Roberts, at the South Landing-Stage.

	A.	B.
	grains.	grains.
Carbonate of lime	28·70	0·64
,, of magnesia	0·00	0·80
Sulphate of lime	144·00	56·44
,, of magnesia	0·00	113·14
Chloride of magnesium	209·00	85·60
,, of potassium	0·00	5·32
,, of sodium	531·00	1295·50
Silica	0·32	0·64
Alkaline nitrates	..	trace
Iodides and bromides	..	trace
Organic matter	1·30	not det.
	914·32	1558·08

In South Lancashire Mr. Mellard Reade has collected valuable information, and reports a well at Cronton near *Prescot*, yielding 800,000 gallons a day, 407 feet in depth; a well at the Iron Works, *Garston*, yielding 240,000 gallons per day, 351 feet in depth; a well of the *Widness* Local Board, with bore-hole 300 feet in depth, yielding 6¼ million gallons per week of 7 days.

In CHESHIRE no returns have as yet been received by Mr. Morton, and he therefore defers reporting on the Wirral wells until next year. For comparison with other districts, it may be well to reproduce the following details.

In sinking the well at Flaybrick Hill in Cheshire, 3400 yards from the Mersey, water began to weep into the well through cavities in the sandstone at 10 feet above high-water mark; above that level Mr. Roberts, who sank the well, states the Keuper Sandstone was free from water; as the depth increased the yield of water became greater, until at 55 feet below high-water mark 350,000 gallons were supplied in 24 hours, which quantity, by a subsequent bore-hole and adit driven to cut a fault by the direction of Mr. Bateman, C.E., was increased to 1,600,000 gallons in the same time.

Professor Hull states that this and the other wells belonging to the Tranmere Local Board, the Birkenhead Commissioners, and the Wirral Water Co., yield together not less than four million gallons.

North-east of England.

Yorkshire.—Prof. Green and Mr. Fox Strangways defer sending the Yorkshire returns, as they are as yet very incomplete.

The following sections of wells in the New Red Sandstone of Yorkshire were collected by Mr. Clifton Ward, F.G.S., of the Geological Survey, and forwarded by him to Mr. Whitaker.

Probable thickness of New Red and Permian in the Leeds and York district:—

		feet.
Trias, 1300 feet.	Keuper (red and blue binds with stone and beds of alabaster)	400
	Bunter (Red Sandstone)	900
Permians, about 300 feet.	Upper Marls	thickness unknown
	Upper Limestone	about 40
	Middle Marls	0 to 30
	Lower Limestone	200

Ascertained thicknesses from rocks, borings, &c., but not all representing *total* thicknesses:—

		feet.
Trias....	Keuper	285
	Bunter Sandstone	700
Permian	Upper Marls	thickness unknown
	Upper Limestone	about 30
	Middle Marls	0 to 30
	Lower Limestone	170

A boring through Magnesian Limestone (Lower) at Tadcaster, 170 feet of Lower Limestone was pierced to the underlying Millstone-grit (rough rock).

Wells and Borings in the New Red and Permian of Yorkshire.

Well at *Selby*:—

	feet.	in.	
Warp and clay	10	0	
Strong clay	10	6	
Sand and clay	14	8	
Strong clay	7	10	
Clay and silt	8	9	
Grey sand or loose water-sand	7	9	
Red sand	6	6	
Indurated sand	1	6	
Red Sandstone	54	6	262 ft. 6 in.
Red clay and Fuller's earth with pipe-clay	5	0	
Red Sandstone	203	0	
	330·0		

(Particulars from Mr. Wainright, Holgate Lane.)

The water is hard (as if from Magnesian Limestone); 243,000 gallons are pumped up every 24 hours, and the supply is constant. The water stands highest at 12 at noon and 12 at night, only varying about 2 inches at these hours, but 8 or 9 inches between these hours.

At the other end of the town (from the Selby Waterworks) there is another well 380 feet deep, still in Red Sandstone; the water stands very near the top.

Another well at Cawood is about 300 feet deep; some years after its sinking, at 11 in the morning of a certain day, the water fell considerably, while at the same hour the Selby well gave an overwhelming supply.

Well sunk by Mr. Swale at Walmgate Bar, York :—

	feet.	in.
Clay and stones	24	0
Quicksand	60	0
Fine sandstone	204	0
Parting with water	0	2
Fine sandstone	279	0
	567	2

At Bilton Hall, near York, sandstone (New Red) reached at 20 yards, not gone through.

Boring at Goole in connexion with a railway-bridge across the Ouse :—

	feet.
Silt and sand	20
Black peat	18
Soft brown clay, sand, and gravel	18
Soft blue shale full of water	18
Strong blue shale with gypsum (here foundation was made)	30
	104

Well at Street Houses in Tadcaster Road (York):—

	feet.
Strong clay	33
Sand	9
(New Red) Red Sandstone	6

Well at *Holme*, near Market Weighton (at 'Blacksmith's Arms') :—

	feet.
(Sunk) Sand	15
(Bored) Blue stone with a layer of "Plaster" at bottom	60
Blue and brown stone	225
	300

(Am not sure about these measures.—J. C. W.)

Sinking and boring at Saltmarsh, 1834:—

	feet.	
Earth	36	
Quicksand	18	
White and blue plaster and red marl	126	201
Blue marl	33	
Red marl	42	
Soft red sandstone	60	
	315	

Boring at Reedness, upon the estate of Mr. John Egremont. Superintended by Mr. John Walker, C.E. (commenced Oct. 7, 1835):—

	feet.	in.
Warp and gravel	69	6
Keuper	272	2
Bunter	687	2
	1028	10

(N.B.—I have all the details of this boring.—J. C. W.)

MIDDLESBOROUGH, Bolckhow and Vaughan, 1861, sunk and communicated by Messrs. T. Docwra and Son. Shaft 178 feet, the rest bored:—

		feet.
	Made ground	1
Alluvium.	Black slime	8
	Sand full of water	10
	Clays	10
	Sand with water	1
	Dry sandy loam	3
New Red.	Hard clay, dry	16
	Claystone, water	11
	Clay with gypsum, dry	7
	Gypsum, water	2
	Red sandstone with gypsum	50
	Gypsum, dry	6
	Red sandstone, a little gypsum	5
	Water	1
	Red rock, dry	4
	„ with gypsum	10
	Blue and white stone	2½
	Red sandstone, no gypsum	720

SOUTH-WEST OF ENGLAND.

Name of Member of Committee asking for information, W. Pengelly, Lamorna, Torquay.

Name of Individual or Company applied to:—

Mr. Shepherd and Sons, Exeter.

1. Bridge Mills, Silverton, near Exeter. **3.** 20 ft., diameter 5 ft., total depth 237 ft.; bore-hole 6 in. diameter. **4.** 214 ft. **5.** 100 gallons per minute. **9.** Sand 94 ft. 8 in.; rock 26 ft. 11 in.; marl 29 ft. 4 in.; clay and greensand 30 ft.; gravel 4 ft. 9 in., water; hard clay 16 ft.; rock 15 ft. 10 in.

Mr. W. S. S. Gamlen, Bramford Speke.

1. In the village of Bramford Speke, Exeter, on a slight eminence at the foot of a long slope of gently rising ground. **2.** 140 feet. **3.** 52 feet; diameter 4 ft. 6 in. **4.** 4 to 5 feet generally; the water returns to this level in about 5 hours. **5.** Cannot say. **6.** About 1 ft. 6 in., higher in winter: I do not think it has varied in quantity. **7.** Only gradually by autumnal rains. The surface of the water is about 2 ft. above the level of the river Exe. **8.** None. Very good drinking-water, slightly hard and containing carbonic acid gas. **9.** Drift of sandy loam 3 to 9 ft., of water-worn gravel 3 to 7 ft.; total cover of drift about 13 ft., then New Red Sandstone to bottom of well, in beds of about 10 ft. of loose sand, 2 of coarser ditto, and 27 of pretty solid sandstone, but not firm enough for building-stone. **10.** About 15 feet below surface of the drift-soil springs occur. **11.** No: they are slight in summer. **12.** No. **13.** No. **14.** No. **15.** No.

Mr. George Pycroft, Kenton, Exeter.

1. Well situated in my house, on a hill-side one mile from tidal river Exe. **2.** 80 ft. **3.** 70 ft., diameter 4 ft. **4.** 13 ft.; do not know, but by two days' pumping I once reduced the level to 3 feet, and it then rapidly refilled. **5.** Not known: well never exhausted. **6.** Yes; it varies from 6 ft. in excessively dry seasons to 13 ft. **7.** Yes. I cannot say, but certainly in 6 hours. The bottom of well about 10 ft. above mean sea-level. **8.** Not known, but not hard; excellent for washing and drinking; well filled to a few feet of the top with carbonic acid; water frequently contains well-shrimps. **9.** New red conglomerate; no cover of gravel or drift. **10.** No cover of drift. **12.** No. **13.** No. **14.** No. **15.** No.

Mr. George Pycroft, Kenton, Exeter.

1. Powderham Castle, right bank of Exe. **2.** 30 ft. **3.** 50 ft., diameter 3 ft. **4.** Not known; never exhausted. **5.** Not known. **6.** Not known. **7.** Is affected by local rains, but how rapidly or to what extent not ascertained; is 20 ft. below the mean sea-level.

8. Saline matters......	14·19 (less)
Organic „	0·62
	14·81
Degree of hardness ..	7·80

9. Light porous red sandstone. **10.** No. **11.** No. **12.** No. **13.** No. **14.** No. **15.** No.

Mr. Robert Blackburn, Trews Weir, near Exeter.

1. Within 50 yards from the river Exe. **2.** 20 ft. above sea-level at Exmouth. **3.** 120 ft. depth of well, and 250 ft. 9 inches bore. **4.** Not ascertained. **5.** 500,000 gallons in 24 hours. **6.** In winter average height of water 2 ft. above summer level. **7.** Not affected by rain. **8.** Analysis of spring-water at Trews Weir: one imperial gallon contains :—

	grains.
Organic matter (including ·168 oxidizing organic matter)	·32
Carbonate of lime..	11·61
Sulphate of lime	5·01
Carbonate of magnesia....................................	5·25
Nitrate of magnesia	6·92
Chloride of magnesia	·41
Chloride of potassium	·79
Chloride of sodium	5·59
Oxide of iron and alumina	·15
Soluble silica...	·75
Total residuum (gained at 140° C., hardness before boiling 27½°)	36·80

9. Red sandstone, rain-drift. **10.** No. **12.** None. **13.** Not known. **14.** No. **15.** None that we know of.

Dr. Lake, Teignmouth.

1. Four wells in garden of Myln Villa, Coomb, West Teignmouth, sunk in 1874 by Teignmouth Local Board as an extra supply for town. These wells are in the bottom of a valley not far from a culvert which was built to carry the water of the brook running in the valley; they are therefore independent of the brook, and are supplied by springs breaking forth out of the rock in their sides and in those of the adit connecting them. **2.** The surface of ground about 100 ft. above mean tide. **3.** 30 ft., diameter 5 ft. **5.** No certain means yet of ascertaining this. **8.** Analysis by Professor Frankland in parts per 100,000:—Total solid impurity 40·00; organic carbon ·056; organic nitrogen ·008; ammonia ·001; nitrogen as nitrates and nitrites ·530; total combined nitrogen ·539; chlorine 3·20; hardness, temp. 11°·4, perm. 11°·1. **9.** See plan. **10.** No. **13.** No. **14.** No. **15.** No.

Dr. Symes Saunders.

1. The well at the Devon County Lunatic Asylum, Exminster. **2.** 150 feet. **3.** 114

feet in depth; bore 70 feet; diameter of shaft 6 feet, ditto of bore 4 inches. **4.** 20 feet before reduced by pumping to 8 feet; restored in 10 hours. **5.** 30,000 gallons. **6.** Yes; in January and February rises occasionally 20 feet. **7.** After continuous rain level is affected and water rises 3 or 4 feet. **8.** Analysis by Voelcker appended. **9.** Red Sandstone. **10.** Yes. **11.** No. **12.** No. **13.** No. **14.** No. **15.** No.

Composition of two samples of Water sent by Dr. Symes Saunders, County Lunatic Asylum, Exminster.

	Well-water. grs.	Water from tap in No. 5 Ward. grs.
An imperial gallon on evaporation left residue, dried at 260° Fahr.	16·61	16·95
An analysis of the residue gave by direct determination:—		
Organic matter and loss in heating	1·39	1·40
Oxides of iron and alumina, traces of phosphoric acid	·24	·25
Lime	3·11	3·24
Magnesia	1·46	1·49
Sulphuric acid	·72	·74
Chlorine	2·20	2·21
Soluble silica	·90	·81
Alkalies and carbonic acid (not determined separately)	6·59	6·81
Total residue per gallon	16·61	16·95
Oxidizable organic matter per gallon	·176	·272

According to the usual mode of combining the constituents of waters, the composition of the two samples may be represented as follows:—

General Composition of two samples of Water in use in the Devon County Lunatic Asylum, Exminster.

An imperial gallon contains in grains:—	Well-water.	Water from Tap in No. 5 Ward.
*Organic matter and loss in heating	1·39	1·40
Oxides of iron and alumina and traces of phosphoric acid	·24	·25
Sulphate of lime	1·22	1·25
Carbonate of lime	4·66	4·87
Carbonate of magnesia	3·06	3·11
Chloride of sodium	3·62	3·63
Carbonates of potash and soda	1·52	1·63
Soluble silica	·90	·81
	16·61	16·95
*Including oxidizable organic matter	·176	·272

AUGUSTUS VOELCKER, Ph.D.

11 Salisbury Square, Fleet Street,
Nov. 2nd, 1866.

Mr. Henry John Carter, Budleigh-Salterton, Devon.

1. All the wells at Budleigh-Salterton are in the New Red Sandstone *above* the great Pebble-bed. **2.** Do not know. **3.** Depth of our own well 37 feet; diameter 3 feet *inside* the revetment *at the top*: I know nothing of any other. **4.** Do not know; water drawn up by bucket three or four times a day; bucket cylindrical iron 15½ by 13½ in. measurement. **5.** Do not know; there is always 4–6 feet of water in our well. **6.** Do not know; well about 150 years old. **7.** Do not know; must be, I should think, 40–50 feet above either at the *bottom*, with the strata inclined south-east. **8.** No peculiarity; comparatively pure compared with that from the land spring, which is so hard that it is only used for washing potatoes and the like. **9.** New Red Sandstone; drift variable in thickness, under 10 feet I should think. **10.** Yes, at our house for 6–8 months in the year. **11.** Entirely kept out, I believe.

12. Do not know. **13.** Not to my knowledge; well 150 years old. **14.** Not to my knowledge. **15.** Not to my knowledge; but the water in many of the wells near the sea, which are comparatively shallower, is very "brackish."

Dr. Albert Baker, Dawlish.

1. In the valley or town, and on the hills on each side of the valley or town of Dawlish. **2.** From 5 ft. to 200 ft. **3.** Varies from 30 to 180 ft.; diameter in sand 3 ft. 9 in., in stone or rock 4 ft. 9 in.; bore-holes not in use. **4.** The average from the "mother" or "main spring" is 7 feet, and if pumped out refills in 7 or 8 hours everywhere. **5.** To be calculated. **6.** Very little when the "mother" spring is struck; there is very little difference, if any, observed in the past 10 years; increase of population 500 to 600. **7.** Only the shallow wells of 14 to 20 feet, which is all from drainage through the lower bed of coarse gravel; this not more than 1 or 2 feet below the stream or sea anywhere. **8.** Not *very* hard; contains a good deal of sulphate of lime (Sorby's), which decreases as you ascend the brook; in many of the low levels it is brackish, but varies very much in adjoining wells. **9.** Generally red sandstone until you reach 60 or 70 feet. The layers run from sandstone to coarse gravel like beach, with veins of fine sand, then large flinty stones and gravel, coarse and large; should hard pan of sandstone be hit, the water will be retained by it, or if bored through it wells up so fast very often that all further sinking is stopped and a permanent supply of 7 feet deep is obtained; at about 40 to 50 feet above the sea water is readily got at 35 feet, but is generally believed to be branch springs and surface percolation together, very pure, but not always permanent. It is believed that *any* well pumped out would refill to 7 feet in from 10 to 12 hours. The various beds vary from 1 to 10 feet or more in thickness; sandstone always predominates in the deep wells. The only well requiring blasting is at "Oaklands," now 65 feet deep and in very hard conglomerate red rock: this well is 200 feet above the sea-level. **10.** Yes, many in various places. **11.** Not generally near wells, but used as open springs and considered very pure. **12.** No. **13.** Never heard of any. **14.** No. **15.** Never heard of any; and the brackish water gets bitter as you get deeper, and is very variable in most places. It appears to me entirely dependent on the loose gravel-beds, which vary in depth and thickness considerably, and no doubt allow the sea-water to percolate through them in high tides, dry seasons, and such like.

Rev. J. Lightfoot, Cofton, near Dawlish.

1. On Cofton Hill, on the right bank of estuary of the Exe. **2.** About 92 feet. **3.** Depth 71 feet, diameter 3 feet. **4.** Height of water 19 feet; no sensible difference after pumping. **5.** Not known. **6.** Do not know; the water has never failed. **7.** Do not know; about 40 feet above mean sea-level. **9.** Light porous sandy rock. **10.** No. **12.** No. **13.** No. **14.** No. **15.** No.

Mr. John Watson, Torquay.

1. Compton Farm, Marldon, near Torquay. **3.** 90 feet deep, 5 feet diameter; no bore-hole. **4.** It is used for the ordinary purposes at the farm-house, and has never been exhausted. **6.** 10 feet in winter and 6 feet in summer. **7.** No stream nearer than half a mile. **8.** Hard. **9.** 10 feet of earth and drift, and the remainder red sandstone. **10.** No. **12.** No. **13.** No. **14** No. **15.** I have no knowledge of any.

Dr. J. A. Colt.

1. At my house at Maidencombe. **2.** About 250 feet. **3.** 91 feet deep, 3 feet diameter; continued to bottom of well. **4.** Ordinary height of water 13 feet 6 inches; no perceptible difference, unless after two or three hours' pumping in dry weather. **5.** Several hogsheads have been pumped in a day without more than 2 inches fall. **6.** No, excepting in the dry seasons of 1868, 1869, and 1870, after severe pumping to supply cattle and neighbours, when it fell to 9 feet 6 inches in October 1870. **7.** The level is not affected to any evident extent by local rains. **8.** It contains a small quantity of lime. **9.** The cover of red-marl drift is about 12 feet thick, and afterwards nearly solid red sandstone rock, with here and there a layer of limestone cobbles cemented in the sand. **10.** No surface-springs; the well is flagged over with large slate flags. **11.** Yes. **12.** No, not nearer than 300 yards, where a well 130 feet deep refused to hold water. **13.** None. **14.** No. **15.** No.

Name of Member of Committee asking for information, Mr. C. Moore, F.G.S., Bath.

Name of Individual or Company applied to:—

Mr. W. W. Stoddart, F.G.S., Bristol.

1. In the city of Bristol. **2.** From 10 feet to 200 feet. **3.** From about 60 feet to 300 feet. **8.** Can give a great number of analyses made for sanitary purposes. A large number of the Bristol wells are reached by tidal water. **9.** Some Triassic marls; some through ditto and Coal-measures, many through peat and gravel. **10.** Yes. **11.** No. **12.** Yes, in Pennant rock. **13.** No. **14.** No. **15.** Yes; will try and get section of the 300-foot well mentioned in No. 3.

Mr. Stuart, Braysdown Colliery.

1. Braysdown Colliery, near Bath. **3.** 500 yards. **6.** Does not vary. **8.** Analysis by Mr. Biggs of water from bottom of pit:—

	grs.
Silica	25·76
Sulphuric acid	31·47
Chlorine *	412·05
Lime as carbonate	62·67
Magnesia	16·09
Soda	332·06
Solid residue after ignition per gallon	920·80
Specific gravity	1·010

Very salt. **9.** New Red Sandstone, Coal-measures. **10.** Surface-springs are kept back, but occur on various points.

Mr. D. Brown, Twerton coal-pit, near Bath.

1. No. 2 pit (sinking), Twerton. **3.** Depth from surface to bottom of shaft 125 yards; diameters 14 ft. × 11 ft. inside welling. **5.** About 16,800 gallons per 24 hours. **6.** Water increases slightly in rainy seasons. **7.** Top spring in gravel-bed 4 ft. 6 in. below water-level of brook; bottom spring 60 ft. 9 in. from level of water in brook. **8.** 112·8 parts per 100,000 of chloride of sodium, estimated purposely by Charles Ekin, F.C.S., Bath.

9. *Section.*

		ft.	in.
	Alluvial and yellow clay	7	6
	Gravel (spring)	1	0
Blue or Lower Lias	Blue clay and plastic shales (with spring)	64	0
	Blue Lias	66	0
Rhætic beds	White Lias	12	0
	Rhætic beds	23	0
	New Red Marl	186	0

10. Yes. **11.** No. **12.** No. **13.** The lower spring was rather salt.

Dr. H. J. Alford, Tangier House, Taunton.

1. Generally within a few yards of dwelling-house. **2.** From 60 to 100 feet. **3.** Various, from 25 to 75 feet. **4.** In some instances in deep water there is difficulty in pumping it dry; it generally fills again in 12 hours. **7.** The shallow wells are so affected. **8.** On analysis the water is somewhat hard, containing sulphate and carbonate of lime; about 6 grains of lime per gallon. **9.** New Red Sandstone gravel subsoil of few feet. **10.** No. **12.** No. **13.** No. **14.** No. **15.** No.

The Rev. O. T. Harrison, Thorn Falcon, Taunton.

1. Thorn Falcon, Taunton. **3.** 25 to 45 feet. **8.** Very hard. **9.** Red marls; spring derived from a sand-bed beneath.

Mr. T. H. Dickinson, Ringweston, Somerton.

1. About 200 yards W.S.W. of Somerton church. **2.** About 95 feet above the river. **3.** Depth 129½ feet, diameter 3 inches. **4.** 47 feet from the surface no variation is noticeable. **5.** Have never tested, but have taken over 3000 in that space of time. **6.** Has not been tested. **7.** Do not think it is.

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* Giving 1008 grains common salt per gallon, or 1440 grains ditto per 100,000.

8. Sulphate of lime ...... 76·40 }
Carbonate of lime...... 53·81 } grains per gallon.
Carbonate of magnesia.. 12·26 }

9. The White Lias is said to be from 90 to 99 feet down; no information in further detail can be given; another well is to be sunk soon about a ¼ of a mile west of this, and a note of the strata will be carefully taken by Mr. Thomas, of Somerton, under whose direction it will be sunk. **10.** There are surface-springs ¼ of a mile west, which supply a good deal of water after rain and various pumps; but I do not apprehend that much goes into this well, and no particular precautions have been taken. **12.** No. **13.** No. **14.** No. **15.** No.

Mr. Edward Tylor, Wellington.

(These answers are given by Mr. Robert Knight, Wellington.)

1. Centre of town of Wellington. **2.** 230 feet. **3.** Well 48 feet deep, 6 feet diameter. **4.** Ordinary pumping does not alter the level perceptibly. **5.** 120. **6.** There is usually 2 feet less of water in the summer: no diminution has been noticed in this well. **7.** Is not affected by rain, and is too remote from streams or sea. **8.** Water pure, particularly "hard" **9.** Loose sandstone covered by about 2 feet of clay. (There is a saying common amongst the country people here, to the effect that the breaking of the springs in winter is in some manner influenced by the winds of the previous March.) **10.** There is no surface-spring within a ¼ of a mile of this well. **12.** No. **13.** No. **14.** No. **15.** No.

Well-sinkers say that within the last 20 years the general level at which water is reached has sunk 1 or 2 feet.

Mr. J. McMurtrie, F.G.S., Radstock.

1. Tyning Pit, Radstock. **3.** Diameter of pit 8 feet; depth to chief spring or feeder 200 feet. **4.** Before pumping, about 90 feet; after pumping, 200 feet. **5.** 864,000 gallons. **6.** It varies a few feet in level summer and winter; the quantity does not diminish. **7.** Local rains increase the feeder; the water rises to the level of the brook in the valley.

	ft.
9. ? Lias	17
Rhætic ....about	18
Red marls	165
	200

10. No drift. **11.** No drift. **12.** None. **13.** None. **14.** None. **15.** None.

Mr. Wilkins, Writhlington.

1. Kilmersdon Coal-Shaft New Pit. **2.** Kilmersdon Pits, one 8 feet, one 10 feet; the 10-foot pit is down 42 fathoms 1 foot 6 in. to a hard stone; 4100 gallons of water per hour come into the pits. **4.** Water rose 33 yds. in 24 hours, and stood at that point. **5.** 24 hours, 98,400 gallons. **6.** This spring rises when the wind is high, but not at any other time, though I have watched it many years. The above spring is what we call "the red-ground spring," and lies from 20 to 24 fathoms under the Lias beds. **8.** Stain red, and when in a vessel the sediment of the water is very red. The water is hard. **9.** Brown clay, Lias and clay, black and blue marl and marlstone 13 fathoms; 34 feet red ground with "lists" of blue stone and conglomerate 4 feet; ditto 1 foot, then red ground 4 feet, then conglomerate again.

[Surface beds Middle Lias, about 3 to 4 feet thick.
Base of Lower Lias .... 37 feet ,,
Base of Rhætic beds............ 5 ft. 4 in. ,,

All the beds above the Coal-measures are very thin in this district.—C. M.] **10.** Yes, lias springs. **11.** Yes. **12.** Yes; fault called the 100-fathom fault. **13.** In coal-measures the water is very salt. **14.** One in the Foxcote pit between the first and second series of veins. I know none but Foxcote.

Mr. E. Barham, Bath, Bridgwater.

1. At Wembdon. **2.** 60 feet. **3.** 30 feet. **4.** Plentiful supply except in very dry summers. **5.** Cannot state precise quantity. **6.** It is level in the summer; three or four years ago there was a partial failure of water in August or September. **7.** No immediate effect is produced by rain, however heavy. The bottom of the well is higher than any other stream in the neighbourhood. I have no analysis of the water; it is very clear to look at and very hard; it "rocks" kettles and sometimes when boiling looks "milky." **9.** The well is entirely situate in the red sandstone, which at the point in question is a band of conglomerate rock, the imbedded rock being, I should think, portions of the Quantock formation. **10.** There are no surface-springs in the immediate neighbourhood. **12.** There is a fault running from near the well past Connington to Charlwick. **13.** No. **14.** No. **15.** No.

The Rev. M. Drummond, Wookey Vicarage, near Wells.

1. West of Wells, Somerset. **2.** About 70 feet. **3.** 33 feet. **4.** 3-feet level does not alter under ordinary usage. **6.** Varies from 3 feet in driest to 12 feet in wettest weather, but no diminution in the supply. **7.** No, probably about level with the river Axe. **8.** No analysis; always clear.

	ft.
9. Red marl	30
Loam	3
Redstone.	

A large body of water finds its way, by means of smaller holes and fissures in the Carboniferous limestone of the Mendip Hills, to the lower levels. Thus a spring rises in the Bishop's Palace Garden at Wells which brings coal with it, some of which I have; and a large stream emerges from under the Carboniferous limestone at Cheddar. **10.** No drift; all the neighbourhood full of land-springs. **11.** Yes. **13.** No. **14.** No. **15.** No.

MIDLAND COUNTIES.

Name of Member of Committee asking for information, Mr. James Plant, F.G.S.

Name of Individual or Company applied to:—

Messrs. Fielding & Co.

1. Leicester. **2.** 210 feet, mean tide Liverpool. **3.** 75 feet, 8 ft. diameter; no bore-hole. **4.** 35 feet, in working reduced to 10 feet and restored in 10 hours. **5.** 250 to 300 thousand gallons. **6.** Not observed; some 10 feet. **7.** Not seen; well when full about same level as water in river Soar. **8.** Sulphate and carbonate of lime; proportions not known.

	ft.	
9. Soil	2–6	(there are two wells).
Drift (clay and sand)	10	
Red marl	30	
*Upper Keuper sandstone	29	
	75	

10. Yes. **11.** Yes. **12.** None known. **13.** No. **14.** None known. **15.** No.

Messrs. Hodges and Sons.

1. Leicester. **2.** 206 ft. above mean tide Liverpool. **3.** 90 ft., 9 ft. diameter, bottom 12 feet diameter; heading driven into sandstone to increase supply. **4.** 50 feet; emptied during ten hours, restored in 14 hours. **5.** No estimate. **6.** Not observed (only sunk 5 years). **7.** Not observed, about same level as river†. **8.** Sulphate and carbonate of lime, proportion not stated.

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* Thin "wayboards" of red and grey marl and red, white, and grey sandstone alternating and full of "ripple-marks;" beds 4 to 6 inches.

† The river Soar, near the town, runs through the "Upper Keuper sandstone" beds, cutting them down to the red marl below; the town of Leicester is partly built on these upper sandstone beds, but drift lies over all.

	ft.
9. Drift	10
Red marl	35
Upper Keuper sandstone	45
	90

10. Yes. **11.** Yes. **12.** None known. **13.** No. **14.** None known. **15.** No.

Messrs. Pickard and Sons.

1. Leicester. **2.** 206 feet, mean tide Liverpool. **3.** 75 feet; no bore-hole; mean width of shaft 8 feet. **4.** 30 feet; emptied in 10 hours, restored in a night. **5.** No estimate. **6.** Not observed. **7.** Not observed same (about) level as river.

	ft.
9. Drift	15
Red marl	25
Upper Keuper sandstone	35
	75

10. Yes. **11.** Yes. **12.** None known. **13.** No. **14.** None known. **15.** No.

Messrs. Everhard and Co. (Brewery).

1. Leicester. **2.** 203 feet, mean tide Liverpool. **3.** 50 feet, diameter 7 feet. **4.** 15 to 20 feet. **5.** Not estimated. **6.** Not observed. **7.** No. **8.** Sulphate and carbonate of lime, proportion not known.

	ft.
9. Drift (clay, &c.)	30
Upper Keuper sandstone	20
	50

10. Yes. **11.** Yes. **12.** None. **13.** None. **14.** None. **15.** No.

Messrs. Rust and Co.

1. Leicester. **2.** 208 ft., mean tide Liverpool. **3.** 80 ft., diameter 9 ft. **4.** 40 ft. **5.** No estimate. **6.** Not observed. **7.** Not observed. **8.** No analysis, simply "hard.

	ft.
9. Soil	10
Drift (clay, sand, and gravel)	30
Upper Keuper sandstone	40
	80

10. Yes. **11.** Yes. **12.** None. **13.** None. **14.** None. **15.** No.

Messrs. John Knowles, Mansfield.

1. Nuneaton, centre of the town. **2.** 210 ft., mean tide Liverpool. **3.** 30 ft., 8 ft. diameter; bore 82 ft., 4 in. diameter. **4.** 105 ft.; no pumping done. **5.** 250,000 gallons in 24 hours. **6.** No (not more than 3 ft. at most); stands permanently 5 ft. above level of river Anker. **7.** Cannot say. **8.** Hard.

	ft.
9. Drift (sand, gravel, and clay)	18
Red marl	12
Lower Keuper sandstone	80
Permian (or Carboniferous)	2
	112

10. Yes. **11.** Yes, by "tubbing." **12.** Great triassic fault (running from N.W. to S.E.) within 200 yards west of well. **13.** None. **14.** None. **15.** None.

Mr. R. C. Sinclair, C.E., Messrs. Howes, Dye Works.

1. City of Coventry. **2.** 220 ft., mean tide Liverpool. **3.** Well 17 ft.; bore 120 ft., 7 in. diameter. **4.** Always flowing over top of well, pump cannot lower it. **5.** Half a million gallons in 24 hours. **6.** Made 1866; never varied since. **7.** Not affected by rains; level of water always 4 ft. *above* level of river, which runs close by. **8.** No analysis; quite clear and bright; no incrustation left on boilers; water considered "soft."

	ft.
9. Drift	11
Red sandstone	1
Conglomerate (Bunter ?)	6
Permian sandstone, very variable in colour and hardness	119
	137

last 2 ft. 6 in. a light grey sandstone so *hard* that the "drilling" cost 2 *guineas per inch*. **10.** Yes. **11.** Yes. **12.** None near this well. **13.** None. **14.** None nearer than Hinckley and Leamington. **15.** None.

Mr. R. C. Sinclair, Coventry Canal Company.

1. Hawkesbury Pumping-station, 4 miles N.E. of Coventry. **2.** 252 feet, mean tide Liverpool. **3.** 120 feet deep, 10 feet diameter. **4.** Before pumping 110 ft.; after 10 days and nights *constant pumping* 95 ft.; fills up in 3 *hours to* 110 *ft.* **5.** In 24 hours 1½ million gallons for weeks together. **6.** Is perceptibly lower after long drought. **7.** No; when engine is not pumping the water stands nearly to the top of well. **8.** No analysis; water very pure, and leaves but little incrustation in boiler.

	ft.
9. Drift	30
Lower Keuper sandstone	90
	120

In sinking through the sandstone but little water was met with until the bottom bed, "a very hard white sandstone," was blasted; the water then burst in; the men had to escape, leaving all the sinking-tools at bottom, and the water rose at once to the above height. **10.** A few. **11.** Yes. **12.** Yes, both east and west. **13.** No. **14.** No. **15.** None.

Hinckley Local Board.

1. The "Holy Well," Hinckley, Leicestershire. **2.** About 330 ft., mean tide Liverpool.

3. Shaft 20 ft.	Bore 520 ft.		
diam. 6 „	diam. 11 in.,	90 ft.	540 ft.
	„ 10 „	12	
	„ 7 „	105	
	„ 4 „	333	

4. Estimated at 420 ft. **5.** No estimate. **6.** Not observed; well not used. **7.** Not observed. **8.** 100 thousand gallons* contain 98 lbs. of sulphate and carbonate of lime (proportion of carbonate not stated) and 2½ lbs. chlorine gas.

	ft.
9. Drift (pebbly clay, sand, and gravel)	150
Red marl	20
Lower Keuper sandstone (viz. *thin* beds of clay and gypsum alternating with *thick* beds of red, grey, and white sandstone)	370
	540

10. Numerous (wells in use all from drift springs). **11.** Imperfectly. **12.** None known. **13.** See analysis ("Holy Well" was a salt spring). **14.** None known elsewhere (there are other wells noted for medicinal properties). **15.** No.

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* Rivers Pollution Commission.

Elmsthorpe Boring.

1. Elmsthorpe, Leicestershire. **2.** 300 ft., mean tide Liverpool. **3.** 1400 ft.; bore 8 in., 6 in., 4 in., 3 in. **4.** 800 ft., constant. **5.** 800 ft. **6.** Permanent level 800 ft. **7.** Not observed. **8.** None.

	ft.
9. Drift	10
Red marl	120
Lower Keuper sandstone	330
Coal-measures	980

these dipping 70° all through. **10.** Yes. **11.** Yes. **12.** 3 miles west great fault in trias (Lower Keuper sandstone). **13.** No. **14.** No. **15.** No.

Lindridge Colliery Company.

1. Lindridge Hall, Desford, Leicestershire. **2.** 400 ft., mean tide Liverpool. **3.** 120 ft., shaft 10 ft. diameter. **4.** Water runs over top of shaft. **5.** Obliged to put engine down before. **6.** Sinking shaft deeper.

	ft.	
9. Drift	2	
Upper Keuper sandstone	20	by boring.
Red marl (marl with thin bands of gypsum)	44	
Lower Keuper sandstone waterstones	204	

10. Yes. **11.** Yes. **12.** East and west fault (downthrow to south) at Hugglescote, 6 miles west. **13.** None. **14.** No. **15.** No.

Austy Paper-Mill Company.

1. Austy, Leicestershire. **2.** 225 ft., mean tide Liverpool. **3.** Shaft 102 ft., diameter 8 ft.; bore 85 ft., diameter 3 in. **4.** No water; bottom of bore gypsum. **5.** No water. **6.** No water. **7.** No water. **8.** No water.

	ft.
9. Drift, stiff brown "boulder" clay with many rounded pebbles	70
Red marl (Keuper), alternate layers of gypsum (6 in. to 12 in.), red clay, white and blue clay	117
	187

10. Yes, all shallow wells in villages. **11.** Yes. **12.** None; is about 1 mile from "igneous rocks" at Groby. **13.** None. **14.** None. **15.** None.

Hathern Boring.

1. Hathern, Leicestershire. **2.** 90 ft., mean tide Liverpool. **3.** 320 ft.? **4.** Water most abundant, height not observed. **5.** Not known. **6.** Not known. **7.** Not known. **8.** Not known.

	ft.
9. Drift	10
Red marl	110
Lower Keuper sandstone	140
Bunter conglomerate	60?
	320

10. Yes, many. **11.** Yes. **12.** 3 miles west of fault in trias. **13.** None. **14.** None. **15.** None.

Chilwell Boring.

1. Chilwell, Leicestershire. **2.** 95 ft., mean tide Liverpool. **3.** 450 ft.; bore 6 in., 5 in., 4 in., 3 in. **4.** Up to the top of bore-hole. **5.** Great abundance, and continuous.

		ft.	in.
9.	Drift	13	8
	Upper Keuper sandstone	53	0
	Red marl	53	4
	Lower Keuper sandstone	115	0
	Upper Bunter (?)	110	4
	Conglomerate	30	8
	Lower Bunter	44	4
	Permian	15	5
		435	9

10. Yes. **12.** Great number N.E. and W. **13.** Great number. **14.** None. **15.** None.

Spinney Hills Company.

1. Humberstone, near Leicester. **2.** 180 ft., mean tide Liverpool. **3.** 600 ft.; bore 8 in., 6 in., 5 in., 4 in. **4.** 400 ft. **5.** No estimate. **6.** No. **7.** No. **8.** None.

		ft.
9.	Drift	6
	Rhætic	12
	Upper Keuper sandstone	100
	Red marl with bands of gypsum	250
	Lower Keuper sandstone	232
		600

10. Yes. **11.** Tube all the way. **12.** None. **13.** None. **14.** No. **15.** No.

North-west of England.

Name of Member of Committee asking for information, Mr. E. W. Binney, F.R.S.

Name of Individual or Company applied to:—

Messrs. Bayley and Craven, Agecroft.

1. 70 yards from River Irwell. **2.** Not known.

3. *a.* 32 ft.×5½ ft.
b. Bore-hole 455 feet deep from surface.. { 312 ft. it is 18 in. diameter.
91 ft. „ 15 in. „
20 ft. „ 9 in. „

4. *a.* 16 ft. from bottom of well before pumping, and 4 ft. from bottom of well after pumping; *b.* 5 or 6 hours. **5.** About 180,000 to 200,000 gallons. **6.** *a.* As we only pump for two or three weeks during dry weather, we have not noticed this; *b.* Yes, probably because not worked continuously. **7.** *a.* We have not noticed this; *b.* The water rises in the well if the river is high. **8.** No analysis; the water contains a considerable quantity of iron. **9.** Stratification in bore-hole only.

	ft.
Red rock	110
„ „ softish	114
„ „ very hard	76
„ „ soft, with various veins of white sandstone from 3 to 6 in. thick	15
„ „ very hard, with various saddle beds	45
„ „ soft, with veins of white sandstone	12
„ „ rather hard	18
„ „ soft, with veins of white sand striæ	23
	413
Not known	20
	433*

* There is an error of 10 feet somewhere in this stratification: it is copied exactly from Messrs. Mather and Platt's report when the bore-hole was made.

10. We believe so. **11.** No. **12.** We have heard of one. **13.** No. **14.** No. **15.** Not that we know of.

Messrs. Andrew & Co.

1. Mount-Street Mill, Harpurhey. **2.** See Ordnance Survey. 6 ft. above the highway well. **3.** 64 yards deep, 7 feet diameter; bore-hole 44 yards deep, 9 inches in diam. for 26 yards, 8 inches for 18 yards: total depth 108 yards. **4.** 20 yards from surface; can empty the well; rises to its level in six hours. **5.** 300 gallons a minute, night and day. **6.** No. **7.** No; above streams 26 to 28 yards. **8.** None; hard, chiefly lime. **9.** Various, chiefly soft red sandstone, soapstone. [Middle Coal-measures.—E. W. B.] **10.** Yes, to a comparatively small extent. **11.** No. **12.** Am not aware [one of 4000 to 5000 ft. close to.—E. W. B.]. **13.** No. **14.** No. **15.** No.

Messrs. Langworthy, Brothers & Co. Mr. John Taylor, Engineer.

3. 12 yards deep, 6 ft. 6 in. diameter. **5.** Plant of four bore-holes, 3½ in. diameter; three of them 60 yards deep and one 180 yards; yields 20,000 gallons per hour perpetually if the pumps are kept at work. Another plant of two bore-holes 60 yards deep, 3½ in. diam., 8000 gallons per hour for about 60 hours per week. **8.** A deposit of lime. **9.** See enclosed sketch of rock &c. passed through to make the bore-hole that is 180 yards deep; it was bored in 1870 and 1871. I think it is the only sketch beyond 60 yards deep that is just in our immediate neighbourhood. **10.** No. **12.** One is supposed to be on the west side of the 4-hole plant, about 100 yards distant. **13.** No. **14.** No. **15.** No.

Name of Member of Committee asking for information, Mr. Mellard Reade, C.E., F.G.S.

Name of Individual or Company applied to:—

Mr. Thomas S. Stooke, C.E.

1. Township of Whiston, Lancashire. **2.** 190 feet. **3.** 75 yards, 9 feet diameter; bore-hole not made. **4.** Works in an incomplete state, as shown by sketch of previous date. **5.** 1,000,000 gallons. **6, 7.** Works in an incomplete state, as shown by sketch of previous date. **8.** Water not analyzed. **9.** Red Sandstone, 3 ft. (no cover). **12.** Yes. **13.** No. **14.** No.

Mr. Robert Winstanley, C.E., Ince Waterworks, Golborne.

1. Golborne, Newton-le-Willows, Lancashire. **2.** Ordnance level, 125 ft. **3.** Well 150 ft. deep, 9 feet diameter; bore-hole 300 ft., 3 in. diameter. **4.** 80 ft., 120 ft.; 6 hours. **5.** 240,000 gallons. **6.** Works established four years; no perceptible change. **8.** Hard water, 11°.

	ft.
9. Surface coal	2
Marl	2
Clay	6
Gravel &c.	9
	19
Red rock, pebble-beds	131
	150

10. No. **12.** Not known. **13.** No. **14.** No. **15.** No.

Messrs. Gaskell, Deacon, & Co.

1. Our three wells are all within 200 yards of the Widnes passenger station. **2.** Surface of the ground is about 10 feet above mean sea-level.

3. No. 1 shaft 30 feet deep, 5 feet diam.; bore-hole 275 yds., average 3 in. diam.
No. 2 shaft 39 „ 12 „ „ 213 „ „ 4 „
No. 3 shaft 37 „ 8 „ „ 143 {51 yds., 9 in. diam. / 92 yds., 6 in. diam.

4. We pump* almost continuously, except at Whitsuntide, when water slowly rises to old level at surface. **5.** Total quantity now pumped from three wells 493,913, or, say, 500,000 gallons per 24 hours. **6.** (*a*) No. (*b*) We fancy so, but have no evidence. **7.** (*a*) Yes. (*b*) In about a month. (*c*) Slightly by rise and fall of tide. No analysis lately; no peculiarity; good ordinary quality for domestic and manufacturing purposes. **9.** Surface, 45 feet of brown clay; quicksand, 18 feet; 135 feet of clay and boulder-clay; red sandstone. **10.** Yes. **11.** No. **12.** Yes; supposed to cut a fault. **13.** No. **14.** None in the immediate neighbourhood. **15.** No; but we know of one or two wells which were sunk close to the river (which is tidal) which were affected by the entry of brackish water through the quicksand.

Widnes Local Board Waterworks.

1. Two wells (A and B) at Litton, near Widnes, about 100 feet apart. **2.** About 10 or 15 feet. **3.** A, 50 feet, 10 feet diameter, without bore-hole; B, 30 feet, 10 feet diameter, with 24-inch bore-hole 300 feet from surface. **4.** A, pumped constantly and hard; cannot state; stands about 40 feet from surface in bore-pipe in B. **5.** 6¼ million gallons per week (of 7 days). **6.** Cannot state. **7.** Yes, in about 10 days. **8.** Dont know of any; nothing particular; very clear, and very slightly "hard." **9.** Soft shaly rock and sand. **10.** No indication of surface-springs. **12.** None known. **13.** No. **14.** No. Believe that one or two have, much nearer the Mersey than ours. The Board's wells are about 2 miles inland.

Mr. E. Timmins, Engineer and Contractor, Runcorn.

1. Stock's Well, Cronton, near Prescot. **2.** 45 feet. **3.** Shaft 50 feet deep, 10 feet in diameter; 1 boring 4 inches diameter, 407 feet deep; 1 boring 24 inches diameter, 307 feet deep from surface. **4.** Before pumping flows over at surface; formerly four hours (six years ago), now twelve hours (July 1875). **5.** 800,000. **6.** It has diminished. **7.** The yield of water increases after several days' rain. The flood-water from "brooks" will rise to within 2 feet of top of well. The brook or sea has no influence upon the well. **8.** The water is soft, very pure, and good for domestic purposes.

	ft.	in.
9. Soil	1	6
Red clay with boulder-stones	28	6
Light blue clunch	6	0
The further sinking and boring soft red sandstone	371	0
Total depth from surface	407	0

10. No. **11.** No. **12.** None been ascertained. **13.** No. **14.** No. **15.** None.

Mr. E. Timmins.

1. At the Iron Works, Garston. **2.** About 15 feet. **3.** Shaft 100 feet deep, 7 feet diameter, and chambered at bottom to 14 feet diameter. One boring 6 inches diameter, 351 feet 6 inches from surface **4.** Before pumping 10 feet from surface, after pumping 80 feet from surface, with bore-valve open; eighteen hours before ordinary level is restored after pumps cease working. **5.** 240,000. **6.** The water-level varies, and has diminished. **7.** The yield of water will increase after a month's wet weather, and is not affected by the brooks or sea. **8.** The water is moderately hard but very pure, and good for ordinary purposes.

	ft.	in.
Soil	1	0
Red clay with boulder-stones	16	0
The further sinking and boring red sandstone	334	6
Total depth from surface	351	6

10. No. **12.** No. **13.** None. **14.** None. **15.** None.

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* During pumping the water is about 35 feet from the surface.

Name of Member of Committee asking for information, Mr. C. E. DeRance, F.G.S.

Name of Individual or Company applied to:—

Mr. Matthew Brown.

1. Pole-Street Brewery, Preston, Lancashire. **2.** 123 feet. **3.** 90 feet, diameter 4 feet. **4.** 12 feet 6 inches before, 5 feet 1 inch after, and rises to 12 feet 6 inches in 40 minutes. **5.** 1015 gallons per hour. **6.** No. **7.** No. **8.** Cannot tell, inasmuch as there is a small supply of water at a higher level than the main spring; and this small supply when analyzed contained 30 per cent. of saline and mineral impurities, the mineral being chiefly iron; and I estimate this small supply, apart from the main spring, would fill a pipe of 1 inch diameter, continually falling into the bottom spring or well. **12.** No. **13.** No. **14.** No. **15.** No.

APPENDIX.

The information collected by Mr. Moore, F.G.S., in the Bristol, Bath, and Radstock coal-field, though not coming strictly within the limits of New Red Sandstone inquiry (the water being chiefly derived from the red marls above it or the Coal-measures), is of interest, as showing the water-bearing properties of these strata.

At Twerton Coal-pit, Twerton, near Bath, 16,800 gallons of water are thrown out every 24 hours by a spring in the Lower Lias, at a depth of 72 feet from the surface; the water was found to contain 112·8 parts per 100,000 of chloride of sodium, by Mr. Ekin, F.C.S., of Bath.

At Braysdown Colliery, 500 yards in depth, a constant volume of water is met with, which Mr. Biggs found to contain 1008 grains of common salt per gallon, or 1440 grains per 100,000: the water appears to be derived from the Coal-measures, and is very salt indeed.

The wells in Bristol, Mr. Stoddart, F.G.S., reports to Mr. Moore are from 60 to 300 feet in depth, situated on heights of from 10 to 200 feet above the sea-level; but the water is derived either from the red marls or the Coal-measures lying beneath; and some of the wells are reached by tidal water.

On the Steering of Screw-Steamers. By Prof. OSBORNE REYNOLDS.

[A communication ordered by the General Committee to be printed *in extenso.*]

THERE does not appear, as far as my observation goes, to be any particular difficulty in steering screw-steamers so long as they are going ahead under steam, but rather the other way; they then seem to be better to steer than almost any other class of ships. Great difficulty often occurs, however, when they are stopping, starting, or otherwise manœuvring. Their vagaries are then so numerous as to give the idea that there is a certain degree of capriciousness and uncertainty about their behaviour. This is, of course, mere fancy; and did we but know them, it is certain that there are laws which these steamers follow under all circumstances. In the hope of arriving at these laws, I have been investigating this subject now for twelve years as opportnnity offered; and I had come, as I thought, to some leading facts, when the failure of the 'Bessemer' to enter Calais Harbour on the 8th of May last seemed to establish them.

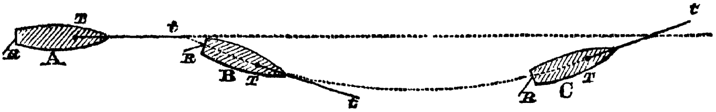
It will be remembered that the ship entered between the piers at a speed of 12 or 13 knots, the tide running strong right across the mouth of the harbour, that on her entering between the piers the engines were reversed, and that the ship turned, under the influence of the current, in spite of her rudder; so that Capt. Pittoch, in his letter to the 'Times,' attributed the accident entirely to her failing to steer at the time.

On reading of the accident I thought it would be a good opportunity to call attention to the subject of steering steamers; and I wrote a paper, which was published in the 'Engineer' of June 4th, 1875, in which I explained why the act of stopping a ship must necessarily affect her power of steering—pointing out that when a ship is stopping the water will be following her stern relatively faster than when she is moving uniformly, and consequently that the effect of the rudder will be diminished; that the longer the ship the greater will be the difference; also that this effect is greatly increased when a ship is stopping herself with her propellers, as was the 'Bessemer'; for then not only is the retardation of the vessel much more rapid, but the water has a forward motion imparted to it by the propellers, which motion, if the propellers are near the rudder, may be greater than that of the ship, under which circumstance the effect of the rudder's action will be reversed. Since publishing this paper in the 'Engineer' I have carried the investigation further; and the object of the present paper is to give an account of some experiments on model boats driven by screws, and the conclusions to which these experiments have led me.

Two models were used in making these experiments; the one 2′ 6″ long, driven by a spring, and the other 5′ 6″, driven by steam. In both models the rudders were broad in proportion to the boats. In the clockwork model the rudder was almost close to the screw, there being no stern-post. In the steam model there was a wide stern-post, and the rudder was an inch and a half behind the screw.

Both boats went straight with their screws driving them ahead and with their rudders straight, and they both answered their rudders easily with their screws going, turning in circles of from four to six feet radius. When the screws were stopped and the boats carried on by their own way, they both answered their rudders, but much more slowly than when their screws were going, the smallest circle being now, as near as I could estimate, from twelve to fifteen feet radius.

In order to try the effect of the screw when reversed on the steering of the spring-model, the model was towed by a cord attached (as shown in the accompanying figure) to a point T amidship about one third of her length from her stern, so that the towing had little or no tendency either to keep her straight or turn her. The rudder was then set at an angle of 45° or thereabouts, so as to turn her head to the right, towing was commenced, the boat turning in a circle to the right. The screw was then started in the reverse direction; whereupon the boat ceased to turn to the right, and commenced turning to the left to an extent depending on the slowness with which she was being towed. When towed very quickly, at from two to three miles an hour, she came nearly straight forward, but at the fastest speed showed no tendency to turn to the right.



The rudder was then set so as to turn the boat to the left, and the operation was repeated with very nearly corresponding results so long as the screw did not race; but the action of the reversed screw on the rudder when set to the left was not so great as when set to the right. This difference led me to suppose that the screw itself might exert an influence to turn the boat to the left when it was reversed, although it had been found to exert no such influence when going ahead. This was at once shown to be the case by setting the rudder straight and starting the screw reversed; the boat immediately turned to the left, but not fast unless the screw raced, then she turned very rapidly.

These direct effects of the screw to turn the ship appear to me to account for several of the anomalies which have hitherto beset the subject; and further on in the paper I shall discuss them at length.

The steam model was provided with paddles as well as screw, and the screw could be reversed without reversing the paddles, in which case the paddles overpowered the screw, and the boat moved forward somewhat slowly. In this boat the screw was so deeply immersed that it would not race, and it had no direct effect to turn the boat when reversed like that of the spring model.

When the screw was reversed and the boat drawn slowly forward by the paddles, the effect on the rudder was almost to destroy its action, it having only a slight power to turn the boat in the opposite direction to that in which it would have turned the boat had the screw been going ahead. Practically the boat had lost all power of steering. Coupled in this way with the paddles the screw turned but slowly, the engine being held up by the opposing actions. On releasing the paddles and allowing them to turn freely, and applying the whole power of the engine to the screw, the model behaved almost exactly as the spring model had done, showing when towed against the screw a strong tendency to turn in the opposite direction to that in which the rudder was set.

The screw was then set full speed ahead; and when the boat had acquired way the rudder was set, so that she began to turn rapidly to the right; the screw was then reversed, and by the time the boat had lost all forward way she had turned to the left through an angle of 30°, so great was the effect of the screw on the rudder when stopping the boat.

This completed the list of the experiments, which, however, were repeated over and over again with exactly the same results.

Conclusions to be drawn from the experiments.—The general conclusion is that in screw-steamers the effect of the rudder depends on the direction of motion of the screw rather than on the direction of motion of the boat. Or we have the three following laws:—

1. That when the screw is going ahead the steamer will turn as if she were going ahead, whether she have stern-way on or not.

2. That when the screw is reversed the rudder will act as if the vessel were going astern although she may be moving ahead.

3. That the more rapidly the boat is moving in the opposite direction to that in which the screw is acting to drive it, the more nearly will the two effects on the rudder neutralize each other, and the less powerful will be its action. It would appear reasonable to suppose that a boat may move fast enough to overcome the effect of the reversal of the screw; but this was not the case with the models.

The effect of the screw to turn the boat independently of the rudder.—It seems to be supposed by some that a screw necessarily tends to force the stern of the boat in a direction opposite to that in which the tips of its lower blades are moving. This is undoubtedly the case when the screw is racing or acting in broken water (*i. e.* water mixed with air), also when the screw is not completely covered with water. When, however, the screw is properly immersed and is working in unbroken or continuous water, and is not affected by dead water, it has not the least tendency to move itself laterally whatever it may have on the ship. Under these circumstances the screw-shaft can exert no lateral pressure on its bearings; and in ships with fine runs this is the case.

Owing to the effect of the dead water, however, it may happen that even when the screw is properly immersed it will tend to move laterally. If the water be following the ship faster above than below (which it often is), the upper blades of the screw will have more work to do than the lower, and consequently they will have to meet with greater lateral resistance; and hence upper and lower resistances will not balance, but there will be a lateral thrust transmitted to the bearings.

Besides the lateral pressure which may be transmitted through the bearings, the screw may also tend to turn the ship by the lateral motion which it imparts to the water, which is again communicated to the ship or the rudder. If the form of the ship and the rudder were symmetrical above and below the screw-shaft, then the effect of the lateral motion which the screw imparts to the water below would exactly balance the effect above the screw-shaft; but owing to the fact that the surface both of the ship and the rudder is in general much greater above than below, the water which is driven laterally by the upper blades has much more surface to act upon than that which is driven in the contrary direction by the lower blades, and therefore drives the stern of the ship laterally or tends to turn the ship. This effect is in the opposite direction to that which arises from the unequal rate at which the water is following the ship as long as both the ship and the screw are going ahead; and consequently these two effects tend to counteract each other. When, however, the screw is reversed, and the vessel is still moving forwards, the two effects are in conjunction; and consequently they are more likely to become apparent and important. This was the case in the experiments with the spring model. When screwing ahead she went straight enough, but when towed ahead with the screw reversed she turned to the left. In this case the effect was small; and I imagine that it must always be so, particularly when the ship has a fine run. In the steam model, of which the run is very fine, the screw-way very large, and the screw small (being only three inches while the boat draws five), the effect of the screw to turn the boat when not racing was altogether imperceptible. I conclude, therefore, that these effects may be left out of consideration with reference to steering; and in opposition to a popular notion I derive law 4.

4. That when not breaking the surface the screw has no considerable tendency to turn the ship so long as the rudder is straight.

The effect of racing.—Although the direct effect of the screw is insignificant when it is not racing or breaking the surface, this is not the case when it is racing. It then exerts a very decided and important effect; and it is doubtless experience of this which has given rise to the popular notion above referred to.

In the experiments with the spring model when the screw was drawing air down, the stern always showed a tendency to move in the opposite direction to that in which the tips of the lower blades were moving, even when the boat was going ahead at full speed and the quantity of air very small; and when the screw regularly raced, frothing the water, its effect to turn the stern of the boat was very great.

The screw of the steam model was so deeply immersed that it would not race; but if the stern of the boat was raised by a string it then raced, and the effect of the screw to turn the stern of the boat was the same as with the spring model.

The screw of the spring model showed a much greater tendency to draw air when reversed (the boat being towed) than when it was driving the boat ahead; but its greatest tendency to race was when the boat was stationary, or nearly so. This latter tendency I have observed in large steamers; in fact I have never seen a large steamer start or reverse her screw when moving but slowly without frothing the water. It appears, therefore, that the effect of racing on the steering may be stated in the following laws:—

5. That when the screw is frothing the water, or only partially immersed, it will have a tendency to turn the stern in the opposite direction to that in which the tips of the lower blades are moving.

6. That when the boat is going ahead its effect will be easily counteracted by the rudder; but when starting suddenly, either forward or backward, at first the effect of the screw will be greater than that of the rudder, and the ship will turn accordingly.

7. That if when the boat is going fast ahead the screw is reversed, at first it almost destroys the action of the rudder, what little effect it has being in the reverse direction to that in which it usually acts. If, then, the screw draws air or breaks the surface, it will exert a powerful influence to turn the ship.

In accounts of collisions it may be frequently noticed that there is contrary evidence given of the steering of one or both of the ships (if they both happen to be steamers). In the instance of the collision between the 'Ville du Havre' and the 'Loch Earn,' the captain of the 'Loch Earn' stated that the steamer altered her course almost at the last moment, thus rendering the collision inevitable. The officers of the steamer asserted that such was not the case; they state, however, that the screw was reversed just before the collision. In this case, therefore, the evidence is to show that the reversal of the screw caused the steamer to change her course, either by its direct effect or by its action on the rudder. The latter effect would be sufficient to explain the facts; and my experiments leave no doubt but that this must have taken place. With regard to the former I have no evidence; although, considering that the ship was moving rapidly at the time, it seems probable that the screw may have raced on being reversed, and added its direct effect to turn the ship to its effect on her rudder. In this case, therefore, the reports of what took place are strictly in accordance with what was to be expected from my experiments; and I think that from the light these throw upon the subject in many cases, the accounts may be less contradictory than they have hitherto appeared; and I am in hopes that in the future these experiments may assist not only in the discovery of the causes of accidents, but, as these become recognized, in the prevention of the accidents themselves.

As an illustation of how important a clear conception of the whole circumstances of the effect of the screw on the rudder may be, I will read an account with which I have been kindly furnished by Mr. Henry Deacon; from which account it appears that a ship was saved by a combination of accidents, which led to her being handled in the very manner in which she would have been had the conduct of the officer in charge been governed by the laws laid down in this paper.

Mr. Deacon says:—

"I have been reading your communication to the 'Engineer' of the 4th inst. about the 'Bessemer's' steering, and think the following narrative may have some interest for you. A friend of mine came from Philadelphia, U. S., early in May to Liverpool in the S.S. 'Ohio.' To avoid ice the vessel went out of her course 160 or 170 miles, and encountered very bad weather. The captain spent one or two days without taking off his clothes; and whilst laying down one day, leaving the chief officer in command of the deck, amongst fogs and rain, an iceberg was sighted right ahead and quite close when seen. The officer stopped and reversed the engines, and put the helm hard round. The cessation of motion awoke the captain, who rushed up the bridge. The excitement had spread, the officer's orders had been strictly obeyed. The captain took all in at a glance, put the engines on ahead at full speed, and the 'Ohio,' breaking through the thin ice always skirting the icebergs, passed so close to the solid mass, that my American friend, who is fond of horses and was on deck, says he could have struck the ice from the ship with a tandem whip. The captain afterwards explained the matter thus:—the steering-gear was the now usual parallel screws, *i. e.* exerting the least force when the rudder is most moved, but of course retaining the rudder in any position with little or no effort. To put the rudder hard round when the ship is under full way and the engines working is an almost physical impossibility; but to put it hard round when the engines are stopped, and especially to put it round when they are reversed, is comparatively easy. The chief officer's order, therefore, enabled the rudder to be put round to the utmost; he both stopped and reversed the engines. The captain's arrival and comprehension completed the manœuvre. The 'way' was but slightly interrupted, but the helm was put hard round and the ship turned from her course in the shortest possible distance.

"I have all this at second hand from my friend; but this fact of the easy movement of the helm whilst the ship was under way with the engines reversed appeared to be one well understood; and of course if no power be required to move the helm, no power can be exerted in steering the vessel; and the whole tale seems to me so illustrative of your remarks on the 'Bessemer,' that I venture to trouble you with it."

Second Report of the Committee on Combinations of Capital and Labour, consisting of Lord HOUGHTON, *D.C.L., F.R.S.* (*Chairman*), JACOB BEHRENS, THOMAS BRASSEY, *M.P.*, FRANK P. FELLOWS, ARCHIBALD HAMILTON, Professor LEONE LEVI, A. J. MUNDELLA, *M.P.*, WM. NEWMARCH, *F.R.S.*, Lord O'HAGAN, R. J. INGLIS PALGRAVE, Professor THOROLD ROGERS. *Drawn up by* Professor LEONE LEVI, *F.S.A., F.S.S.*

YOUR Committee appointed to inquire into the economic effects of combinations of labourers or capitalists, and into the laws of economic science bearing on the principles on which such combinations are founded, have already stated in their preliminary Report, made last year, the course they have thought fit to take in order to ascertain the exact views held by both employers and employed on the subject in question. Although the general objects of such combinations, whether of capitalists or labourers, are well known, both from the written rules which bind them together and from the action taken from time to time, your Committee have deemed it desirable to come into personal contact with some representative men from both classes, with a view of finding whether they do now stand by the rules of their Unions and how far they are prepared to defend them; and for that purpose your Committee resolved to hold a consultative private conference of employers and employed in the presence of the members of the Committee, where they might discuss the questions involved in the resolution of the British Association, with a view of reporting thereon to the same. The points more especially inquired into were the following:—

1st. What determines the minimum rate of wages?

2nd. Can that minimum rate be uniform in any trade? and can that uniformity be enforced?

3rd. Is combination capable of affecting the rate of wages, whether in favour of employers or employed?

4th. Can an artificial restriction of labour or of capital be economically right or beneficial under any circumstances?

For the discussion of these questions your Committee had the advantage of bringing together a deputation from the National Federation of Associated Employers of Labour, consisting of Messrs. R. R. Jackson, M. A. Brown, H. R. Greg, Joseph Simpson, J. A. Marshall, R. Hannen, and Henry Whitworth; as representing labour—Messrs. Henry Broadhurst, Daniel Guile, George Howell, Lloyd Jones, George Potter, and Robert Newton (Mr. Macdonald, M.P., and Mr. Burt, M.P., having been prevented from attending); and on the part of your Committee, Lord Houghton, Professor Rogers, Mr. Samuel Brown, Mr. W. A. Hamilton, Mr. Frank Fellows, and Professor Leone Levi were present.

Many are the works and documents bearing on the questions at issue. Of an official character we have the Report of the Royal Commission appointed "to inquire into and report upon the organization and rules of trade-unions and other associations, whether of workmen and employers, and to inquire into and report on the effects produced by such trade-unions and associations on the workmen and employers and on the relations between workmen and employers and on the trade and industry of the country." Of an unofficial character we have the Report of the Committee of the Social Science Association "on the objects and constitution of trade-societies, with their effects upon wages and upon the industry and commerce of the country." Of special works we have the late lamented Professor Cairnes's 'Leading Principles of Political Economy,' Mr. Thomas Brassey's 'Work and Wages,' and Professor Leone Levi's 'Wages and Earnings of the Working Classes.'

The chief functions of combinations, whether of capital or labour, being to operate on wages, your Committee were anxious to ascertain by what criterion the parties interested ordinarily judge of the sufficiency or insufficiency of existing wages. The first test of the sufficiency of wages is the relation they bear to the cost of the necessaries of life. "The minimum of wages," said Prof. Rogers, "is the barest possible amount upon which a workman can be maintained; that which, under the most unfavourable circumstances, a man is able to obtain." But the minimum thus estimated can only be, and is, submitted to under circumstances of extreme necessity. "I believe the minimum rate of wages," said one of the representatives of labour, " is that which, under the worst circumstances, the worst workman gets from the worst master." We cannot, therefore, take the minimum rates so considered as a proper basis for the sufficiency of wages. How far insufficient wages in relation to the cost of living in the United Kingdom is a cause of the large emigration which is taking place from year to year it is not possible to establish * ; but doubtless the prospect held out in the distant colonies and in the United States of America of considerable improvement has been for some time past, and still is, a strong inducement to those in receipt of insufficient wages in this country to emigrate to other lands. Your Committee are desirous to point out in connexion with this question that not only has the cost of some of the principal necessaries of life greatly risen within the last twenty years †, but that, in consequence of the general increase of comfort and luxury, many articles of food, drink, and dress ‡ must now be counted as necessaries which some years ago were far beyond the reach of the labouring classes; whilst house-rent, especially adapted for the labouring classes, is considerably dearer. If, therefore, the cost of living be taken as a guide to the rate of wages, it would not be enough to take into account the cost of the mere necessaries of life. A higher standard of living having been established, it is indispensable to compare the wages of labour with such higher standard. Your Committee are not satisfied, however, that it is possible to regulate wages according to the scale of comfort or luxury which may be introduced among the people, and are compelled to assert that it is an utter fallacy to imagine that wages will rise or fall in relation to the cost of such supposed necessaries or indulgences.

A better test of the sufficiency of wages is the relation they bear to the state of the labour-market; and tested by that standard the minimum rate of wages which workmen are at any time prepared to accept is the least which they think they are entitled to have under existing circumstances, the

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* The average number of emigrants in the last ten years from the United Kingdom, from 1862 to 1873, was 230,000 per annum. In 1873 the total number was 310,612, and in 1874 241,014. The emigration to the United States decreased from 233,073 in 1873, to 148,161 in 1874.

† The prices of the principal articles of food in the five years from 1852 to 1856 and 1868 to 1872 are shown in the following Table.—

	Wheat.		Mutton	Beef.	Potatoes.
	per qr.		per lb.	per lb.	per ton.
	s.	*d.*	*d.*	*d.*	*s.*
1852-56	62	0	5·62	5·10	105
1868-72	54	8	6 35	6 15	110
1873 ..	58	8	7 68	7 03	138
1874 ...	55	8	6·56	6·59	140

Report of Registrar-General of Births, Deaths, and Marriages.

	Butter.	Cheese.	Tea.		Sugar.	
	per lb.	per lb.	per lb.		per lb.	
	d.	*d.*	*s.*	*d.*	*s.*	*d.*
1856-58	11 41	6·50	2	10	0	5
1871-73	10 38	6	1	6	0	3¼

Report of Local Government Board.

‡ The consumption of articles of food and drink per head in 1864, 1873, and 1874 was:—

	Bacon.	Cheese.	Rice.	Sugar.	Tobacco.	Wine.	Malt.	Home Spirits.	Foreign Spirits.
	lbs.	lbs.	lbs.	lbs.	lb.	gal.	bush.	gal.	gal.
1864 ...	3 77	3·13	5·72	36 83	1·29	0 39	1·75	0 69	0·21
1873 ...	9·07	4·69	11·37	51·59	1·41	0·56	1·98	0 91	0 32
1874 ..	7·84	5·03	10·18	56 37	1·44	0·53	1·94	0·94	0 32

trade-unions guiding them as to the state of trade and the value of labour at the time. Unfortunately, however, what workmen think themselves entitled to have does not always correspond with what employers find themselves able to grant. Primarily the wages of labour are determined by the amount of capital available for the purposes of wages in relation to the number of labourers competing for the same. But the amount of capital employed in any industry is itself governed by considerations of the relation of the cost of production to the market-price of the produce (that is, to the price which the consumer is able or willing to give for the same)—the cost of production including the cost of materials, the value of capital, the cost of superintendence, and the wages of labour.

Objection was taken at the Conference to this method for arriving at the rate of wages; and it was urged that instead of taking the price of the article produced or the interest of the consumer as the basis of the calculation, the first ingredient in the cost of the article should be the price to be paid to the workman in producing it. But a serious consideration will show that the employer cannot ignore what the consumer can or will pay any more than the share which the value of capital, the cost of superintendence, and the cost of the materials have upon the cost of production; for he must cease producing altogether if he cannot both meet the ability of the consumer to purchase his article and successfully compete with the producers of other countries. Your Committee think that it is not in the power of the employer to control the proportion of the different elements in the cost of production, each of them being governed by circumstances peculiar to itself. The value of capital as well as the value of the raw materials are regulated by the law of supply and demand, not only in this country but in the principal markets of the world. The cost of superintendence and the wages of labour are likewise governed by the relation of the amount of capital to the number seeking to share in the different employments. The employed say, "We must have certain wages. We care for nothing else. Labour is our property. We set our value upon it. If you will have our labour you must pay what we ask for it; and if such wages should require a rise in the market-price let the consumer pay it." What, however, if the consumer will not or cannot pay sufficient price to enable the employer to pay such wages? What if he can get the article cheaper elsewhere? Must not production cease if there be no market? And where will be the wages if there be no production? Nor should it be forgotten that a general rise of wages producing an increase of the cost of all the commodities of life reacts on the masses of the people, and thus far neutralizes the benefit of higher wages.

Disagreements between employers and employed are often produced on the subject of wages by the fact that all the elements of the case are not within the cognizance of both parties, experience showing that, in making a demand for an advance of wages or for resisting a fall, workmen are of necessity groping in the dark as to the real circumstances of the case. One of the chief advantages supposed to result from the organization of trade-unions is the competency of their leaders to give solid and practical advice to those interested as to the condition of the labour-market; and we have no doubt that this duty is in the main honestly performed; but it is very much to expect that such leaders should universally possess large and liberal views enough to vindicate the exercise of their enormous power, and such constant and accurate knowledge of the various facts of the case as would enable them to be an almost infallible authority. On the other hand, were it possible for employers, who are not in the dark in such matters, to make known to their own workmen the grounds of the action they propose taking before the resolve is carried into execution, your Committee are convinced that many disputes would be avoided, and much of the jealousy which now exists between the parties would be removed. The recent lock-out in South Wales illustrated the need of such a course. Had the facts which Lord Aberdare elicited from the principal colliery firms in Glamorganshire been made known previous to or simultaneously with the notice of a fall, it is a question whether such a widespread calamity would have occurred. It is, perhaps, a natural but unfortunate circumstance that employers are seldom found to take the initiative in allowing a rise in wages when the state of the market permits it as they are in the case of a fall, and spontaneously to offer what they must sooner or later be compelled to grant. A more prompt and politic course on their part in this matter would go far to neutralize the hostile action of trade-unions.

Your Committee were anxious to ascertain how far is it in the mind of the employed that the employers obtain for themselves too large a share of profits at their expense. Your Committee were assured that no such doubts are entertained, though cases were produced supporting such suspicions by reference to the time of the great rise in the price of coals in 1873, when workmen's wages did not, in the opinion of the representatives of labour, rise to any thing like the proportion of the masters' profits *. Your Committee admit that in cases of great oscillations in prices, the share participated either by the employers in the shape of profits, or by the employed in the shape of wages, may be for a time greater or less than their normal distribution would justify. And it is possible that some portions of these extra profits may be unproductively spent or so employed as not to benefit the parties more immediately concerned, and even used in totally alien speculations. Yet, in the main, the working classes must receive, in one way or another, a considerable advantage from them, there being no doubt that the largest portion of such extra profits will be reinvested in the ordinary industries of the country. In the end, however, wages and profits will be divided among the producers in proper proportions; and if at any time profits or wages should be larger than they ought to be, we may be quite sure that ere long the competition of capitalists will tend either to the lowering of prices or the raising of wages, so as to make profits and wages gravitate towards each other.

Immediately allied to the question of the determination of a minimum of wages is that of their uniformity. In the opinion of many trade-unions, all workmen of average ability in any trade should earn the same wages, the average ability of each man being understood to have been determined in advance by the fact of his being admitted as a member of the union. But a man is subject to no examination, and is generally admitted upon the testimony of those who have worked with him, whose evidence must frequently be fallacious and insufficient. Nor does it appear that the rejection is absolutely certain even if the applicant should not be deemed a man of average ability, the acceptance or rejection of the party being always optional with the lodge to which he is introduced. Your Committee are therefore not satisfied that any guarantees exist that every member of a

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* Mr. Halliday's evidence before the Committee of the House of Commons on coals was that, though the custom was to give to workmen a portion of any rise of prices in the shape of increasing wages, the proportion being an additional *2d.* a day for every *10d.* a ton, the rise in wages was often *1d.* per ton only, and sometimes nothing, whilst when the price rose *2s. 6d.* to *5s.* a ton, the wages were only increased *3d.* a day.

union is able to earn a fair day's wages for a fair day's work; and they cannot, therefore, agree in the proposition that all workmen should be entitled to uniform wages on the ground of uniform ability. But another reason has been alleged for the uniformity of wages, which is still less tenable than the former, viz. a supposed uniformity of production independent of skill. The right of the workman to a uniform standard of wages was stated to be the production of an article which, though demanding less skill to perform, is of equal utility, and is proportionally as profitable to the employer. Your Committee must, however, entirely demur to the principle that, in the apportionment of wages, no account should be taken of the skill brought to bear on the execution of the task, since a system of that nature would act as a premium on inferiority of workmanship. Again, by another test should the right of each individual to earn certain wages be determined, and that is by his productive capacity. Professor Levi asked whether that was taken into account when the workman was assumed to be of average ability; and the answer was that the amount of production depended largely upon the skill. "The more skilful a man is the more he will produce." But whilst in so far this answer was correct, it contradicted the principle embodied in the preceding test; the answer itself did not take sufficiently into account that skill is not the only element in effectiveness of labour. There are qualities of mind, judgment, and even of heart, disposition, and of moral character, which go far to increase or diminish the efficiency of labour; and of such qualities the employer is, of necessity, a far better judge than any union can be. That under ordinary circumstances wages in any trade should tend to uniformity is quite possible. The facility of communication and the extension of intercourse of necessity equalize prices and wages; but any attempt to compel uniformity of wages among any large number of men of varied capacity must of necessity prove a source of disappointment. Much, again, may be said in favour of a common standard of wages in any industry, as avoiding the embarrassment necessarily encountered in any attempt to adjust the rate to the exact worth of each individual. Yet it is impossible to ignore the fact that whilst a uniform rate is sure to operate unjustly in favour of persons who may be wanting in fairness of dealing or capacity for workmanship, in the nature of things it is almost incapable to exist over a wide area, having regard to the varieties in the prices of fuel, carriage, house accommodation, or of the means of livelihood, as well as in the cost of raw materials and in the processes employed as affecting the rate of production of each individual. On the whole, your Committee find that an absolute uniformity in the rate of wages in any trade, though to a certain extent convenient, is neither just nor practicable, whilst any effort to compel uniformity in the amount of earnings of any number of individuals must prove fallacious and wrong as an illegitimate interference with the rights of industry.

A still more important question in connexion with the subject is how far combination of any kind can affect permanently or temporarily the rate of wages. Upon this, as might be expected, the most divergent opinions are held by the representatives of capital and labour. The employers of labour, standing on the solid principles of political economy, deny that combinations can, under any circumstances, affect the rates of wages, at least in any permanent manner—the argument adduced being that if workmen are entitled to higher wages they are sure to get them, since, under the law of supply and demand, whenever it is found that profits trench unduly upon wages fresh capital is sure to be introduced which provides for the raising of wages.

The employed, on the other hand, confidently appeal to past experience, and point to the fact that almost every increase of wages has been due to the action of trade-unions. They say that without combination workmen cannot secure the market-price of their labour, but are to a certain extent at the mercy of their employers; that in trades where one establishment employs a large number of workmen the employers can discharge a single workman with comparatively slight inconvenience, while the workman loses his whole means of subsistence; that without the machinery of combination the workmen, being dependent upon their daily work for their daily bread, cannot hold on for a market.

Your Committee are not prepared to deny that combinations can render useful service in matters of wages; but they think that it is impossible for them to frustrate or alter the operations of the laws of supply and demand, and thereby to affect permanently the rates of wages. Combinations may hasten the action of those laws which would undoubtedly, though perhaps more slowly, operate their own results. The limited power of combinations is in effect admitted by the workmen themselves. "We do not say," said one of the workmen's representatives, "that trade-unions can absolutely interfere with supply and demand, because when trade is very bad they cannot obtain the standard; when it is good they easily raise the standard. What they do is, they enable workmen sooner to strike at the right time for a general advance. They get the advance sooner than if they were an undisciplined mob, having no common understanding; and when trade is receding, the common understanding enables workmen to resist the pressure put upon them by their employers. It helps them in both ways, and the workmen find they can act together beneficially." The ground here taken by the working men is not at variance with sound economic principles. But there is yet another way in which trade-unions may prove useful, and that is by rendering wages more sensitive to the action of the state of the market, and so preventing the influence of custom to stand in the way of the operation of supply and demand; for there are such occupations, as agriculture, where custom often exercises imperious rule even upon wages. As it has been well said by M. Batbie, "Wages do not change unless the causes for the change exercise a strong influence. If the conditions of supply and demand do not undergo a great change, wages continue the same by the simple force of custom. The variations of wages are not like those of a thermometer, where the least clouds are marked, where one can read the smallest changes of temperature. They may rather be compared to those bodies which do not become heated except under the action of an elevated temperature, and remain quite insensible to the slight modifications of the atmosphere. Until a great perturbation takes place in the conditions of supply and demand, no one would think of changing the rate of wages" *. After making every allowance your Committee cannot admit that combinations have any power either to raise permanently the rate of wages or to prevent their fall when the conditions of trade require the same, as recent experience abundantly shows; and whilst admitting that combinations may be beneficial in accelerating the action of economic laws, your Committee cannot be blind to the fact that they produce a state of irritation and discontent which often interferes with the progress of production.

Limited as is the power of combinations to affect the rates of wages, still more limited is their power to affect materially the progress of productive industry. The Royal Commission on Trade-Unions reported that it was

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* See M. Batbie's article on "Salaires" in Bloek's 'Dictionnaire de la Politique.'

extremely difficult to determine how far unions have impeded the development of trade, whether by simply raising prices or by diverting trade from certain districts, or from this to foreign countries. The representatives of capital at the Conference alluded to endeavoured to prove that certain branches of trade have permanently been injured by the unions. Whether the fact can be established or not, it is undeniable that British trade has enormously increased within the last twenty years, and that the exports of manufactured goods are on a larger scale now than they were at any former period *.

What is perhaps most objectionable in combinations of labour is the method they often pursue in order to operate on the rates of wages; for they are not content with making a collective demand on employers for a rise, but endeavour to force it, or resist a fall, by restricting the supply of labour and increasing the need of it. One such method, explained at the Conference, seems to your Committee peculiarly objectionable. A representative of labour said, "That when depression of trade comes, by means of associated funds, the men are liable to say to the surplus labourers 'stand on one side, you are not wanted for the time being; if you go on with your labour at half price, it will not mend the trade: we will not let you become a drug on the market, putting every other man down, but we will sustain you.'" In three years, your Committee were informed, over £100,000 was thus paid for unemployed labour, in the hope that undue fall in wages would be prevented by keeping labourers out of the market. Your Committee are of opinion that the artificial prevention of a fall of wages, when such a fall is necessary and inevitable, is economically wrong, and can only have the effect of still more injuring the condition of workmen, since by so doing they only throw hindrances in the way of production, which is the parent of all wages. Equally objectionable in your Committee's opinion, as interfering with the freedom of labour and with the general economy of production, is every regulation of such trade-unions that excludes from employment in the trades all who have not been regularly apprenticed, or any rule which should set a limit to the number of apprentices. Professor Cairnes, commenting on the monopoly thus advocated by trade-unions, said, "It is a monopoly, moreover, founded on no principle either of moral desert or of industrial efficiency, but simply on chance or arbitrary selection; and which, therefore, cannot but exert a demoralizing influence on all who come within its scope—in all its aspects presenting an ungracious contrast to all that is best and most generous in the spirit of modern democracy."

The only other question on which your Committee will report is whether an artificial restriction of labour or of capital can, under any circumstances, be economically right or beneficial. It is, indeed, scarcely necessary to say that any restriction of labour or of capital having the effect of limiting pro-

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* The following were the quantities of some of the principal articles of British produce and manufacture exported from the United Kingdom in 1854 and 1874:—

	1854.	1874.	Increase. per cent.
Coal and coke..................	4,309,000 tons.	13,927,000	223
Copper	274,000 cwts.	709,000	159
Cotton yarn	147,128,000 lbs.	220,599,000	49
Cotton manufacture	1,692,899,000 yds.	3,606,639,000	113
Iron............................	1,175,000 tons.	2,487,000	112
Worsted manufacture	133,600,000 yds.	261,000,000	71

The total value of British produce exported increased from £135,891,000 in 1860 to £239,558,000 in 1874, or at the rate of 76 per cent.

duction, must of necessity prove injurious. Yet it may be a point for consideration whether, under certain circumstances, it may not be better for either labour or capital to submit to the evil of restriction, in order to avoid a still greater evil, of producing at a loss, or working at rates of wages not sufficiently remunerative. The labourers justify their proceedings in this respect by reference to the practice of producers. One of the representatives of labour, speaking on this subject, said:—"No doubt there is not a working man in Lancashire who would not say that limitation was an injury. Generally that there should be the largest possible production in a given time is no doubt a true law; but every trade must regulate that according to its own necessities. The ironmaster blows out his furnaces when an increased production would injure; the cotton manufacturer runs his manufactory short time; and the labourer limits the production." There is little or no difference in the relative position of capital and labour as respects their need of continuous production. Primarily both employer and employed alike depend upon production as the only source for profits and wages. Whilst the employers have the maximum interest in producing as much as possible, from the fact that the fixed capital, which they cannot withdraw, would lie dormant and unproductive while the forge or mill is silent, the employed find it their interest to aid in such production, inasmuch as they depend upon it for their means of subsistence. The argument of the employed against a proposal for a reduction of wages is expressed in the words:—"If you have too much of an article in the market and you cannot sell, I would rather limit the quantity in your hands than aggravate the evil and take less money for it." But by refusing to work when the employer is able or willing to continue producing, or by not submitting himself to accept lower wages when the inevitable law of supply and demand compels the same, the employed only aggravates his own position, whilst he places the employer in a still worse strait; the certain consequence of the withdrawal of labour being to discourage production, to enhance the cost, and to increase the difficulty of foreign competition—injurious alike to the producer and to the whole community.

A frequent source of contention between employers and employed is the mode of paying wages, viz. by time, such as by the day or hour, or by piecework. There appears to be no uniform practice on the subject. While in some branches of industry the rule is to pay wages by piecework, in other branches the rule is to pay by time—the reason probably being that whilst in some branches it is easy to establish a scale of prices at which the work is to be paid for, in other branches such a scale could not easily be framed. In so far as the method of payment can be considered to affect production, it seems to your Committe that whilst payment by piecework is likely to promote quantity of production, payment by time is more likely to promote precision of execution. Your Committee cannot believe, what has often been alleged, that payment by piecework is often offered to conceal any reduction of wages. If honestly acted upon on either side, payment by piecework has, in the opinion of your Committee, all the elements of fair justice. But the question in any case is not of sufficient importance to justify a breach of the friendly relation which should exist between capital and labour. When either party has any decided preference for one system, it seems advisable that the other party should accept the same.

The economic effects of strikes and lock-outs are well known, and it matters but little which party in the contest in the end may prove successful. In recent years strikes and lock-outs have occurred among coal- and iron-miners the building-trade, engineers, the cotton-trade, ship-builders, and most of the trades and industries of the country, each and all of which have caused serious losses on the community at large. In the opinion of your Committee a well-devised system of conciliation is the only proper and legitimate method of solving labour-disputes. And your Committee cannot too strongly express their sense of the grave responsibility which rests on either employers or employed when, regardless of consequences, they resort to a step so vexatious and destructive as a strike or lock-out.

Your Committee are of opinion that the British Association will confer a lasting benefit if, on its pilgrimage in the principal industrial towns in the United Kingdom, it will seize every opportunity for the enunciation of sound lessons of Political Economy on the questions in agitation between employers and employed. It was suggested to your Committee that workmen should be admitted to the meetings of Section F at a reduced rate. Your Committee desire to point out the importance of promoting, as far as possible, the study of political economy, and especially of those branches of industrial economy which most intimately concern the industry, manufactures, and commerce of the country. Your Committee have learned with pleasure that the Cobden Club are prepared to offer some encouragement for the teaching of political economy to the labouring classes; and your Committee would suggest that the Chambers of Commerce might advantageously take similar means in the great centres of commerce and manufacture. In the opinion of your Committee, a proper sense of the necessity and utility of continuous labour, an earnest desire for the achievement of excellence in workmanship in every branch of industry, and a keen and lively interest on the part of one and all to promote national prosperity, are the best safeguards against the continuance of those disturbances between capital and labour which have of late become of such hindrance to successful production. In the great contest which Britain has to wage with other industrial nations, it is the interest of both masters and men to be very careful lest, by raising the prices of British produce and manufacture too high, they should no longer be able to carry the palm in the arena of international competition.

Your Committee regret the death of their much esteemed member Mr. Samuel Brown, who took an active part in the proceedings. Professor Fawcett, M.P., was unable to act. But your Committee have pleasure in reporting that the Right Hon. Lord O'Hagan, Mr. Thomas Brassey, M.P., and Mr. A. J. Mundella, M.P., were added to the Committee.

Second Report of the Committee, consisting of W. CHANDLER ROBERTS, Dr. MILLS, Dr. BOYCOTT, A. W. GADESDEN, and J. S. SELLON, *appointed for the purpose of inquiring into the Method of making Gold-assays, and of stating the Results thereof. Drawn up by* W. CHANDLER ROBERTS, *F.R.S., Secretary.*

IN their last Report the Committee stated that portions of the gold plate, which had been so long in course of preparation, had been sent to various distinguished chemists on the continent and in America.

Several Reports have been received, all of which confirm the favourable opinion the Committee expressed as to the purity of the plate. Towards the close of the year the Secretary visited M. Stas in Brussels, and received from him details of the experiments which he had made in testing the metal, the results proving that the plate contained 999·95 parts of pure gold in 1000. The minute trace of foreign matter which is admixed with the gold was probably derived from the clay crucible in which the finely divided metal was melted. Mr. J. Norman Lockyer, F.R.S., has photographed the violet and ultra-violet parts of the spectrum produced by the electric arc when pieces of this gold are employed as terminals, side by side with the solar spectrum; and the result proves that neither silver, copper, nor iron, the metals which might have been expected to be present, exists in sufficient quantity to be detected by the spectroscope.

With the completion of this standard plate an important step has been made in that a common standard for reference has been secured. With regard to the discrepancies between the results of different assayers, the Committee propose to collect evidence in the hope of being able to ascertain whether the causes of difference are introduced at the second or fourth stages of the operation, or, in other words, in the furnace or while parting with acid.

Eighth Report of the Committee, consisting of Prof. EVERETT, Sir W. THOMSON, *F.R.S.*, Prof. J. CLERK MAXWELL, *F.R.S.*, G. J. SYMONS, *F.M.S.*, Prof. RAMSAY, *F.R.S.*, Prof. A. GEIKIE, *F.R.S.*, JAMES GLAISHER, *F.R.S.*, Rev. Dr. GRAHAM, GEORGE MAW, *F.G.S.*, W. PENGELLY, *F.R.S.*, S. J. MACKIE, *F.G.S.*, Prof. HULL, *F.R.S.*, Prof. ANSTED, *F.R.S.*, Prof. PRESTWICH, *F.R.S.*, *and* C. LE NEVE FOSTER, *appointed for the purpose of investigating the Rate of Increase of Undeground Temperature downwards in various Localities of Dry Land and under Water. Drawn up by* Prof. EVERETT, *Secretary.*

THE supposed difficulties in the way of obtaining observations of temperature in the St.-Gothard tunnel have vanished of themselves. On a recent visit to the tunnel, your Secretary had the pleasure of meeting Dr. Stapff, who has for two years filled the post of official geologist to the "Direction" of the Gothard Railway, and has in that capacity made the temperature of the tunnel a special object of investigation. Dr. Stapff's observations are contained in successive numbers of the Monthly and Quarterly Reports of the Chief Engineer to the "Direction," and of the Swiss Government Engineer to the subventing States, on the progress of the Gothard Railway. A paper on the subject was read by Dr. Stapff at a recent meeting of the Swiss Society of Naturalists held at Andermatt in the immediate neighbourhood of the tunnel; and an abstract of it has been kindly communicated by him to the Secretary, accompanied with tables and diagrams.

Dr. Stapff's observations were of three kinds:—

I. Observations of rock-temperature, made with very long thermometers, inserted in horizontal bore-holes, of depth not exceeding one metre, in the sides of the tunnel. The air was excluded by a firm plugging of tallow all along the stem, which was of such length that the scale projected into the air and could be read without disturbing the instrument. They were graduated to

0·2 of a degree Centigrade, and read by estimation to 0·05, all necessary corrections being applied, including a correction for temperature of stem. The index-errors were known from comparison with standards, attention being paid to the difference between the reading in a vertical and in a horizontal position, which, on account of the great length of the column of mercury and consequent pressure on the interior of the bulb, amounted to about half a degree. As the thermometers were costly, and were very liable to be broken in the process of extraction, these rock-observations were comparatively few.

One of the Committee's protected Negretti maximum thermometers was left by the Secretary with Dr. Stapff, and has been used by him for verifying some of his previous observations, the thermometer being pushed to the bottom of the hole, with a cord attached, and the hole being then tightly plugged with rags and tallow.

A minimum thermometer would have been more appropriate, as the rock was colder than the air; but the Rutherford's minimum which the Secretary had provided was too large for the holes. Besides, it is doubtful whether the index could be trusted to retain its place during the extraction of the thermometer. The extreme slowness of action of the protected Negretti maximum was the one quality which rendered its use possible, and a non-registering thermometer possessing the same characteristic would be more appropriate. It was accordingly agreed between Dr. Stapff and the Secretary that a new pattern of non-registering thermometer should be constructed with a special view to slowness of action. This end is to be attained by surrounding the bulb with tallow or some other non-conducting solid, the whole being inclosed in a sealed glass tube. [Six thermometers on this plan have since been constructed by Negretti and Zambra, and two of them, after satisfactory trials, were forwarded by the Secretary to Dr. Stapff on the 1st of November.]

II. Observations of air-temperature in the tunnel. The air is artificially warmed by the presence of the workmen, by their lamps, and by blasting; and, on the other hand, is cooled by the escape of the compressed air from the boring-engines. Dr. Stapff states that, notwithstanding these disturbing influences, he "gradually fell into a uniform system of observing air-temperature, so that the *mean* results obtained were useful." He further found that the mean air-temperature thus determined at any point *when first laid open* by the driving forward of the narrow gallery (to be afterwards widened) was identical (to a fraction of a degree) with the rock-temperature afterwards observed at the same point at the depth of a metre in the walls. For example, at the distance of 800 metres from the Swiss portal the rock-temperature, 1 metre deep, was 17°·85, the mean air-temperature when first observed having been 17°·80. Again, at the distance of 1443 metres from the Swiss portal the rock-temperature, 1 metre deep, was 18°·16; the mean air-temperature when the heading had just advanced to this point was 17°·29, the temperature at the same time from 20 to 40 metres further back being 18°·35. The last observations made at the Italian end on the occasion of the verification of the axis of the tunnel confirm this conclusion as to the approximate identity of the air-temperature in the extreme end of the heading with the temperature of the surrounding rock.

III. Observations of the temperature of springs. In the Swiss portion, up to the date of the Secretary's visit, there were no springs of any account; but in the Italian portion they are numerous. When water-filled crevices (in the Italian portion) are first bored through, the water issues with the velocity due to a height of some 2 or 3 metres; but as soon as such a cleft is totally opened, the water runs down all around the perimeter of the gallery without showing signs of pressure. Springs from the bottom (which are by no means rare) have never shown signs of pressure.

The temperature of springs is higher when they are first tapped than at any subsequent period. The springs at the distance of from 780 to 820 metres from the Italian portal fell, in the first fourteen days, from 10°·52 to 9°·75 C., and those at the distance of from 1495 to 1500 metres from the Swiss portal, which had a temperature of 17°·1 when tapped in November 1874, have now fallen to 16°·2, after the lapse of ten months.

The temperature of springs, even when first tapped, is lower than that of the surrounding rock. The average amount of this difference for the first 2200 metres from the Italian portal was 3°·14 C. In the first 1200 metres it was generally greater, and in the remaining 1000 metres always less than this average value. At 2180 metres it was reduced to ·77 of a degree. As these differences constitute one of the most noteworthy results of Dr. Stapff's observations, they are here presented in tabular form. The degrees are Centigrade.

Distance from Italian portal, in metres.	Temperature of rock, deduced from observations in air.	Temperature of springs.	Difference.
	°	°	°
100	11·50	8·42	3 08
200	13·43	8·00	5·43
300	15·00	8·30	6·70
400	13·13	8·80	4·33
500	11·03	8 79	2·24
600	11·53	8·75	2·78
700	13·03	8·77	4·26
800	14·08	10·63	3·45
900	14·84	10·37	4·47
1000	15·04	11·38	3·66
1100	17·18	13·30	3·88
1200	16·97	13·35	3·62
1300	17·38	14·88	2·50
1400	17·63	15·25	2·38
1500	18·21	—	—
1600	20·45	17·40	3 05
1700	20·84	18 60	2 24
1800	20·64	18·70	1·94
1900	21·71	19·00	2·71
2000	21·38	19·80	1·58
2100	20·95	20 05	·90
2180	21·27	20 50	·77
		Mean	3·14

The strongest springs are those in the first 1300 metres from the Italian portal. Their temperature varies, to the extent of a few tenths of a degree, with the quantity, as dependent on rainfall, being lowest when the quantity is greatest.

The conformation of the ground and the course of the tunnel are such that at equal distances from the two portals the Italian portion is the more distant from the surface. It is not, however, upon the whole, warmer than the Swiss portion; but for distances (from the portals) intermediate between 200 metres and 1400 metres is decidedly colder—an effect, probably, of the abundant infiltration of cold water.

The tunnel has now been carried to a distance of 2500 metres at the Swiss and 2200 metres at the Italian end; and the temperature of the rock, as deduced from air-observations, is—

At 2400 metres from Swiss portal .... 21°·7 C.
„ 2180 „ „ Italian „ .... 21°·3 C.

The distances from the surface (measured in the nearest direction) are 306 metres in the former case (the plain of Andermatt being overhead), and 1090 metres in the latter. The mean temperature at Goschenen (the village at the Swiss end) is 6°·82 C.

Observations were taken (Aug. 17th, 1874) by Mr. John Donaldson, C.E., in a pump-well 413 feet deep, at Mr. Sich's brewery, Chiswick, near London. The pumps were kept idle all day to facilitate observation. The thermometer used was a protected Phillips's maximum. During the first series of observations, pumping was going on from a well in a neighbouring brewery, an operation which lowers the level of Mr. Sich's well by about 3 inches. This pumping was discontinued before the completion of the second series. The surface of the water is 60 feet below the surface of the ground. The diameter of the well is 5 feet to the depth of 200 feet, and is less than one foot (and gradually diminishing) for the remainder of the depth. The following are the observations:—

Depth from surface of ground.		Temperature in degrees Fahr.	
ft.	in.	First Series.	Second Series.
		°	°
65	0	55·5	56·2
105	6	54·6	54·5
155	9	54·5	54·5
205	9	54·9	55·0
256	2½	55·0	54·9
306	7	55·5	55·4
358	1	56·6	56·6
395	5	57·5	58·0

The difference between the two observed temperatures at 65 feet is attributed to the disturbance of the water by passing the thermometer and suspending wire through it. The difference of half a degree between the two observations at the bottom is attributed to the discontinuance of pumping in the next brewery, as mentioned above. These temperatures (57°·5 and 58°·0 at the depth of 395 feet) may be compared with the temperatures observed by Mr. Symons in the Kentish-Town well at the depth of 400 feet, as given in our Reports for 1869 and 1871, namely 58°·1 and 57°·9. The agreement is satisfactory, as indicating, on the one hand, that even where there is strong convective action (as in this pump-well) the temperature near the bottom is but slightly affected; and, on the other, that where there are no strong springs the temperature at intermediate depths (the Kentish-Town well being 1100 feet deep) is likewise nearly free from convective disturbance.

A boring in search of coal is being made at Swinderby, about eight miles to the west of Lincoln, in which observations have been made by Mr. J. T. Boot, the engineer of the works. The depth attained on July 19, 1875, was 1535 feet, the strata penetrated being:—(1) Lower Lias, 140 feet; (2) New Red Marl (Keuper), 569 feet; (3) New Red Sandstone (Keuper and Bunter), 790 feet. The boring is now in red marl of the Permian formation. A great feeder of water was met with at 790 feet on penetrating the Lower Keuper Sandstone, and another at 950 feet in the Bunter Sandstone, the water from the latter rising above the surface. The bore-hole is being lined with tubes.

The best observations were taken on the 15th, 16th, and 17th of June, 1875, the hole having remained undisturbed since May 27th. These observations were as follows:—

Date.		Depth.	Temperature. Fahr.	Time down.	
		feet.	°	h	m
June 15	....	100	68	1	0
,,	....	200	68½		30
,,	....	300	68¾		30
,,	....	400	68¾		30
,,	....	500	68¾		30
,,	....	600	69		30
,,	....	700	69		30
,,	....	800	69		30
,,	....	900	69		30
June 16	....	1000	69⅛		35
,,	....	1100	69⅛		35
,,	....	1200	69½		30
,,	....	1300	70⅛		35
June 17	....	1400	71		35
,,	....	1500	73		40

At an earlier date, May 13th, the hole having been undisturbed for a few days, the temperature 68¼° was found at 1308 feet, which was the depth then attained, and the temperatures 66°, 66°, 66°·2, 66°·6 were found at the respective depths of 0, 300, 490, 590 feet. The instrument employed on both occasions was the protected Negretti maximum thermometer.

These observations illustrate the difficulty of obtaining correct results in the presence of strong springs of water. It is obvious that nearly all the above temperatures are largely affected by convection. If we assume the temperature at the bottom in each case to have been free from this source of error, as well as from disturbance by the heat generated in boring (assumptions which are somewhat doubtful), and if we estimate the surface-temperature at 49°, we have the following mean rates of increase:—

Between	0 feet	and	1308 feet	....	1° F.	for	68	feet.
,,	1308	,,	1500 ,,	....	1	,,	40	,,
,,	0	,,	1500 ,,	....	1	,,	62·5	,,

A bore-hole is being sunk to a depth of 2000 feet at Böhmisch-Brod, near Prague; and the Secretary has received two independent applications for thermometers for the purpose of making observations in it—one of them from the Academy of Sciences of Vienna, the other from the Imperial Polytechnic School at Prague. Two thermometers (one of the Negretti and one of the Phillips pattern) were supplied in each case, the expense being defrayed by the recipients. These applications are gratifying, as tokens of an increasing interest in the subject of underground temperature.

Two protected Negretti thermometers have been sent to Dr. Oldham, Director of the Geological Survey of India, to be used in borings for coal in that country. Arrangements are also being made by Mr. Blanford, Director of Meteorological Observations for India, to establish regular observations of earth-temperature at small depths at certain selected stations.

The following thermometers have also been issued:—

To Mr. J. A. Bosworth, a protected Negretti, to be used in a deep boring in Shropshire.

To Mr. Atkinson, of Newcastle, a similar instrument, to replace one broken in his previous observations.

To Mr. Pengelly, a protected Phillips, for a boring at Torquay.

Tides in the River Mersey. Half-tide Level at Liverpool.

By James N. Shoolbred, *C.E.*

[A communication ordered by the General Committee to be printed *in extenso.*]

[Plate IV]

In the year 1835, at the Meeting of the British Association in Dublin, Captain (now Admiral) Henry Mangles Denham, R.N., Resident Marine Surveyor of the Port of Liverpool, announced "that, from observations which he had been enabled to take on the rise and fall of a number of tides in the River Mersey, he had ascertained that there was an oscillating point or mean centre which every six hours is common to all tides, whether spring or neap, and called the half-tide mark or level."

In 1837 Captain Denham further announced to the Association, at its Meeting in Liverpool, "that the oscillation of each tide, whether spring or neap, passed this line, viz. the half-tide level, at three hours before and three hours after every high-water time, and not at the half-elapsed time of high and low water."

Captain Denham considered this half-tide mark, though not a suitable one to adjust soundings to, to be a most valuable datum for tide-gauge operations, or as a point of departure for engineering levelling-operations—a remark which was subsequently fully confirmed by the selection of the "level of mean tide at Liverpool" as the datum level for Great Britain for the Ordnance maps.

It will be seen, therefore, that this subject of the half-tide level is one that has already received some attention, and has had a practical and important application.

It appears, therefore, not out of place to make a few remarks on this half-tide level, and as to its real nature, especially as much information as to the action of the tide in the Mersey has been obtained during the interval of forty years that has elapsed since Capt. Denham first broached the subject.

In the latter part of 1853 a self-recording tide-gauge was established at Liverpool, near to the St. George's Pier-head, advantage being taken of one of the bridges which connected the floating landing-stage to the shore, the rising and falling of the bridge with the tide being communicated by a chain arrangement to a self-recording drum driven by clockwork and there suitably registered.

These observations had been continued without interruption, save for short repairs, since the above date until twelve months ago, when they were necessarily suspended, owing to the burning of the landing-stage and the removal of the connecting-bridge during its reconstruction.

As, however, the whole of the stage is expected to be again open for use in the course of a short time, and as the connecting-bridges are now in position, it may be confidently anticipated that the self-recording of the tides may be again soon resumed.

By the courtesy of the present Marine Surveyor to the Mersey Docks and Harbour Board, Staff-Commander Graham H. Hills, R.N., the writer has had an opportunity of inspecting a number of the resultant diagrams of the tidal curves.

After careful examination of many tides, the writer confesses himself quite unable to agree with Capt. Denham in his definition that "the half-tide level is an oscillating point or mean centre which every six hours is common to all tides, whether spring or neap," or with the assertion "that the oscillation of each tide, whether spring or neap, passed this line at three hours before and three hours after every high-water time."

Some difference of opinion seems to exist as to the interpretation of the term "mean or half-tide level." The method by which this level appears commonly if not generally to be arrived at is by taking the mean of a number of levels of high water for a mean high water, then of a nearly similar number of low-water ones to form a mean low-water level, the difference between these two means giving a mean tidal range, the half of which amount, being reckoned upwards from the mean low-water level, gives an absolute level called the mean or half-tide level—in fact the mean half-range of the tide.

Whether this is exactly what Capt. Denham meant by his "oscillating point or mean centre," is uncertain. But it is without doubt that this half-range varies considerably, not only with successive tides, but even over lengthy periods, such as a year in duration, or even a duration of years.

The writer has been enabled, by the courtesy of the Marine Surveyor, to place upon the diagram hereto appended (Plate IV.) the annual means at Liverpool for high water, for low water, for tidal range, and for the half-tide level for the twenty years extending from 1854 to 1873—each year being represented by a vertical line with its date upon it, and the position of its mean of high water, low water, and half-tide level indicated upon it to a scale of a quarter of an inch to one foot. The irregular line at the top of the diagram is formed by the junction of the annual means of high water, the mean high water for the twenty years being indicated by a horizontal line. The low-water means are similarly treated at the bottom of the diagram; while in the middle of the sheet the half-tide levels are described in a like way.

The datum to which they are reduced is the sill of the Old Dock at Liverpool, a datum much in use in that neighbourhood.

A very brief inspection of the diagram will show that there is considerable variation in each of the means between different years, amounting, in more than one case, to nearly twelve inches. And if so with annual means, how much greater the irregularity in shorter periods!

If, therefore, by "half-tide level" Capt. Denham means the level of half-tide range, his idea of "an oscillating point common to all tides" cannot hold good, seeing that the result of the twenty years' observations shows considerable differences to have existed in the "half-tide level" between the several years, in some cases nearly nine inches.

It may, however, be urged that some of the variations occurring in the course of this lengthened period are caused by the altered form of the course of the tidal channel of the River Mersey near to its mouth, to its being gradually narrowed and made more direct by each successive prolongation of the river-wall of the Liverpool Docks.

While admitting that something may be due to this cause (a matter not yet proved), there still exists sufficient irregularity, shown sometimes in one direction and sometimes in another, at times also when no new alterations in the form of the channel were taking place, to disprove the accuracy of Capt. Denham's theory of a permanent oscillating point as far as regards the tides in the Mersey.

As to his second assertion, "that this half-tide level line is passed by the oscillation of each tide at three hours before and three hours after high-water time, and not at the half-elapsed time of high and low water," its value can only be ascertained by a close inspection and analysis of the tidal diagrams themselves.

The writer can, however, state the opinion of the present Marine Surveyor of Liverpool (who has had charge of these tidal observations almost ever since their commencement, and therefore is intimately acquainted with them), who considers that this assertion of Capt. Denham's is quite untenable.

The selection of the half-tide level at Liverpool as the datum for the Ordnance Survey of Great Britain was made after a series of tidal observations carried on in 1859 at a number of ports round the coast of England*.

In the Ordnance book, 'The abstract of Levelling in England and Wales,' 1861, it is defined in the following terms:—"The datum level for Great Britain is the level of mean tide at Liverpool, as determined by our own observations; it is $\frac{8}{10}$ of an inch above the mean tidal level obtained from the records of the self-recording tide-gauge on St. George's Pier, Liverpool."

These records, as will be seen by the annexed Table, give the mean half-tide level for the five years preceding 1859 as 4·948 feet above the Old Dock Sill. If to this be added the $\frac{8}{10}$ of an inch (·066 foot) referred to in the Ordnance book, a total of 5·014 feet above Old Dock Sill (the zero of the tide-gauge at the St. George's Pier) is obtained as the level of the Ordnance datum, a difference which is quite borne out by the actual levelling of several engineers.

The Ordnance book of levels already referred to gives, in another portion of the book, in the column of levels only 4·67 feet as the difference between the Ordnance datum and the zero of the tide-gauge. While, to render the discrepancy still more intelligible, no doubt, the printer has omitted the *minus* sign before the last-named level, so placing the zero of the tide-gauge *above* the half-tide level—thus introducing a possibility of error (to strangers to the locality) of over *nine feet* in the comparison of these two important systems of levels (the Ordnance and the Old Dock Sill).

When it is considered of what importance to the country are those most carefully prepared maps of the Ordnance Survey, and the system of levels which they introduce, it will be readily seen that it should be a matter of paramount importance to dispel any discrepancy or uncertainty which may exist as to the very *fons et origo* of that system of levels.

In conclusion, it must not be supposed from the above remarks that the writer, while adducing the irregularity of the half-tide level at Liverpool, as evidenced by the result of twenty years' observations, wishes to argue against the *practical* uniformity of the mean level of the open sea all the world over —a fact which is being each day more fully admitted. Liverpool is not on the open sea but on an estuary, and one where the conditions of the channel have been altered considerably during late years by engineering structures.

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* Since writing the above, it appears, from a communication received by the author from the Ordnance Office at Southampton, that "the assumed mean water at Liverpool depends upon tidal observations taken by this Department in March 1844," and that the 1859 observations published in the Ordnance book are those of the self-registering tide-gauge.

Records of Tides in River Mersey at Liverpool, taken by the Self-recording Tide-gauge at the George's Pier-head, Liverpool.

Date.	Mean H. W. *above* O. D. S.	Mean L. W. *below* O. D. S.	Mean Tidal Range.	Mean Half-tide Level *above* O. D. S.	Means of 10 years.	Means of 20 years, 1854–1873.
	ft.	ft.	ft.	ft.	1854–1863. H. W. (above O. D. S.)... 15·562 feet. L. W. (below O. D. S.) ... 5·567 ,, Tidal Range .... 21·129 ,, Half-tide Level (above O. D. S.) .... 5·011 ,,	H. W. (above O. D. S.)... 15·757 feet L. W. (below O. D. S.)... 5·527 Tidal Range .... 21·283 ,, Half-tide Level (above O. D. S.) .... 5·124 ,,
1854.	15·423	5·546	20·969	4·938		
1855.	15·366	5·570	20·936	4·898		
1856.	15·513	5·466	20·979	5·023		
1857.	15·519	5·531	21·050	4·994		
1858.	15·349	5·575	20·924	4·887		
Means of 5 years.	15·434	5·533	20·973	4·948		
1859.	15·661	5·477	21·138	5·107		
1860.	15·573	5·556	21·129	5·126		
1861.	15·638	5·438	21·076	5·100		
1862.	15·777	5·551	21·328	5·113		
1863.	15·799	5·958	21·758	4·920		
Means of 5 years.	15·689	5·596	21·285	5·073		
1864.	15·743	5·923	21·666	4·910	1864–1873. H. W. (above O. D. S.)... 15·953 feet. L. W. (below O. D. S.)... 5·486 ,, Tidal Range .... 21·440 ,, Half-tide Level (above O. D. S.) .... 5·237 ,,	
1865.	15·848	5·980	21·828	4·934		
1866.	16·041	5·708	21·749	5·166		
1867.	16·150	5·443	21·593	5·353		
1868.	16·445	5·139	21·584	5·653		
Means of 5 years.	16·045	5·639	21·684	5·208		
1869.	16·116	5·617	21·733	5·250		
1870.	15·820	5·663	21·483	5·078		
1871.	15·708	5·206	20·914	5·251		
1872.	16·232	4·832	21·064	5·700		
1873.	15·430	5·354	20·784	5·038		
Means of 5 years.	15·861	5·334	21·196	5·265		

Datum: Old Dock Sill (O. D. S.) at Liverpool.

Sixth Report of the Committee, consisting of the Rev. THOMAS WILTSHIRE, *M.A., F.G.S.,* Prof. WILLIAMSON, *F.R.S., and* JAMES THOMSON, *F.G.S., Secretary, appointed to investigate the Structure of the Carboniferous Corals.*

DURING the past year the Committee have conducted their investigations and have made sections of upwards of 300 specimens. In order that they might arrive at as clear a conception as possible of their specific value, the Secretary went over to Paris, and examined the types of MM. Milne-Edwards and J. Haime, and also those of Prof. de Koninck in Belgium, and compared them with the structural details as delineated in the Plates already prepared; and the result of his investigation warrants them in saying that they are glad they have not published more than brief abstracts of their investigations. The delay has also enabled them to try several methods for delineating the intricate and delicate structure of many of these corals, well knowing that their structure could not be reproduced by the ordinary process of lithography. The system adopted is the result of many experiments, and the one most suited for the purpose, as by it can be given facsimiles of the most delicate structure, thus placing in the hands of students the means whereby they can name either genera or species even from small fragments.

The results of the investigations and comparison of the type forms referred to point to three new genera. The varieties, however, are so numerous, that it was felt desirable to make other sections before determining distinct varieties.

The following have been determined, and are engraved upon what they provisionally term Plate XII.

Aspidiophyllum, Thomson, gen. nov. The generic name is taken from the form and position of the boss in the centre of the calice, it being helmet-shaped. As the characters upon which the generic distinction is founded have been described in detail in the Transactions of the Philosophical Society of Glasgow for 1874, the descriptions need not be repeated. The generic and specific names of those published are:—

Figs. 1 & 1A.	*Aspidiophyllum*	*Koninckianum*, Thomson, sp. nov.
2.	„	*Huxleyianum*, Thom., sp. nov.
3.	„	*Hennedii*, Thom., sp. nov.
4.	„	*cruciforme*, Thom., sp. nov.
5 & 5A.	„	*elegans*, Thom., sp. nov.

In *Aspidiophyllum Huxleyianum* one of the primary septa is shorter than the others, with a clavate tube-like process lying in the plane of the open interseptal spaces. Around the inner margin of the tube-like body are grouped a number of ovule-like bodies, much resembling ova. Detailed accounts of these are published in the Transactions of the Philosophical Society of Glasgow for 1874.

Plate XII. figs. 10, 11, 12, 14, 15, and 16 belong to the same genus, but differ from those described in essential specific characters, and will be described hereafter.

Plate XIII. contains representations of seven species of the genus *Rhodophyllum*, Thomson, gen. nov., which have been described in the 'Geological Magazine,' viz.:—

Figs. 1 & 1 A. *Rhodophyllum Craigianum*, Thomson, sp. nov.
3. „ *Slimonianum*, Thom., sp. nov.
4. „ *Phillipsianum*, Thom., sp. nov.
6 & 6 A. „ *simplex*, Thom., sp. nov.

Figs. 2, 5, 7, and 8 belong to the same genus, and will be described along with the former genus.

Plate XIV. contains representations of a new genus, which the Secretary discovered at Brockley, near Lesmahagow, Lanarkshire, many years ago. It exhibits characteristics hitherto unnoticed. The Secretary proposes calling it *Kumatiophyllum*. It has at least ten good species, which will be described as before stated.

Plate XV. is another Plate partially prepared, but is not sufficiently forward to be described in this year's Report.

Third Report of the Committee, consisting of Sir JOHN LUBBOCK, *Bart.*, Prof. PRESTWICH, Prof. T. M'K. HUGHES, Prof. W. BOYD DAWKINS, Rev. H. W. CROSSKEY, Messrs. L. C. MIALL *and* R. H. TIDDEMAN, *appointed for the purpose of assisting in the Exploration of the Settle Caves (Victoria Cave). Drawn up by* R. H. TIDDEMAN, *Reporter*.

[PLATES V. & VI.]

WORK was carried on almost uninterruptedly throughout the year, except from March 20th to May 20th, when it was stopped for want of funds. An appeal to the public by the Settle Committee was made, and at the end of two months they considered themselves justified in recommencing work.

It is a matter of much interest to the Committee that the last subscription received (on Jan. 10th, previous to stopping the work for want of funds) was from the late Sir Charles Lyell, and unsolicited. Sir Charles had taken a deep personal interest in the explorations from their commencement, had visited the Cave, and been a frequent subscriber to the fund.

The Glacial Beds.—It will be remembered that in the last Report at Belfast we drew attention to the evidence respecting the pre- or interglacial age of the lower deposits in the Victoria Cave, which contain the early Pleistocene fauna associated with a human fibula. Since that time further evidence in this direction has been obtained. The great mass of boulders which lies upon the edges of the Lower Cave-earth at the entrance and beneath all the screes or talus has been further followed; and the facts brought to light are very interesting, and throw much light upon the origin and deposition of the glacial beds.

The boulders have now been uncovered over an area of about 30 × 40 feet, or 1200 superficial feet (see Plates V. & VI. and descriptions), and probably extend beneath the screes over a still greater area. As before, the boulders are of all sizes and of various origin. Of the limestone boulders a large proportion are of blue or black limestone, and not of the white limestone in which the cave is excavated. They probably come from the top of the Carboniferous Limestone, which is widely exposed in the country to the north around the foot of Penyghent. One large boulder, on the other hand, an easily recognizable rock, consists of a portion of the *base* of the Carboniferous Limestone, which is a conglomerate of Silurian pebbles in a matrix of limestone, and must have travelled at least two miles to its present position. Other boulders consist of Carboniferous Sandstone or Millstone-grit, but a very large proportion are of Silurian rocks.

In size they run from large blocks several tons in weight to mere sand-grains, for the passage may be easily observed. At one place you have large boulders in a matrix of stony clay, then a clayey gravel, the component stones well scratched and bruised as only glacial deposits are, then fine gravel, still of the same character, shading off into sand. The sand again gives place to laminated clay of the finest character.

A very interesting section showing this has been lately uncovered; it lies at the back of the boulders, and contains several beds of laminated clay, sand, and gravel intercalated with indisputable glacial deposits.

This may be regarded as a positive proof that some at least of the laminated clay is of glacial age and origin.

In removing some of the boulders at the entrance, a step which the progress of the work necessitated, we appear at length to have come upon the solid floor of the cave-mouth. We found several long, wedge-like masses of rock, with their apices upwards, sticking up from amongst the boulders. They seem to run along definite lines, the spaces between which coincide with the vertical joints traversing the roof and side of the cave.

They stand up in pinnacles, and are not unlike in form similarly weathered floors in other caves in Craven. We may mention Browgill Cave near Horton in Ribblesdale, which is now occupied by a stream. This peculiar form seems to have arisen from the water working down along the joints and slowly dissolving the limestone, leaving an edge projecting upwards, in some cases almost as sharp as a knife. That the Victoria Cave was once a stream-course there can be no doubt; not only these limestone pinnacles, but the peculiar weathering of the side of the cave at the entrance into a succession of arched niches corresponding with the joints (another characteristic of water caves) render this tolerably certain (see Plates V. & VI. and descriptions).

And now, with the additional evidence of another year's diggings, we may again consider the question (the most interesting perhaps of all the problems before us)—Are the glacial deposits, which rest upon the older bone-beds containing the extinct pleistocene mammals and man, in the position which they occupied at the close of glacial conditions, or have they subsequently fallen into their present site?

We may again urge the reasons given last year, strengthened by enlarged sections and a wider experience, which go to prove the first alternative.

1. The cliff immediately above the cave is free from any boulder deposits for a considerable distance.
2. The boulders lie at the base of all the talus, which must have been forming ever since glacial conditions declined, and no other falls of even isolated boulders have occurred throughout the whole thickness of talus.
3. The boulders are so close beneath the cliff, that if all the limestone which has fallen from it and is now lying on the boulders could be restored to the cliff, it would project so much further forward, that the fall of the boulders from the cliff to their present position would be impossible.

To these arguments we may now add the following:—

4. That the extent of the glacial deposits now exposed is so great that it is impossible that they can be a mere chance accumulation of boulders which have been redeposited in their present position since glacial times.

This being the case, it is clear from the position of the boulders beneath all the screes that they form a portion of the general glacial covering of the valleys and hillsides which was left by the ice-sheet at the time of its disappearance.

These are the main arguments to be derived from the cave itself; but further strong presumptive evidence that the Pleistocene fauna lived in the north of England before the ice-sheet exists as follows:—

The older fauna once lived in that district, a point which admits of no dispute from its existence in the Victoria Cave, in Kirkdale Cave, Raygill Cave in Lothersdale, and perhaps in other caves; but their bones are now found nowhere in the open country. None of the river-gravels contain them; and just that district which is conspicuous by their absence is also remarkable for the strongest evidences of great glaciation. If these facts be taken together, the probability is very strong that it was glaciation which destroyed their remains in the open country.

To suppose that they have been destroyed by other subaerial agencies would be to ignore the fact that in the south of England and other non-glaciated areas such remains exist both in caves and in river-gravels. This view your Reporter has held for some years; a somewhat similar view has been well stated by Mr. James Geikie, and Prof. Boyd Dawkins also agrees in it.

Bones beneath the Talus and on the Boulders.

In removing the talus, certain bones were found lying beneath it upon the boulders.

They have, so far as practicable, been determined by Prof. Busk; and he gives the following account of them.

"They are nearly all fragments, but No. 1 is perfect.

"1. Right calcaneum of *Ursus arctos*, 3·4 inches long, 2·2 wide, 1·75 high.

"2. Portion of a young, much worn left calcaneum of *Ursus*, with anterior and posterior epiphyses detached.

"3–67. Small chips and fragments, mostly apparently of the shafts of long bones and ribs of ruminants. Doubtfully referred to Ox? Deer? Goat? or Sheep?

"68. Fragment, probably Elephant.

"69. Fragment of a large Deer-bone.

"70. Fragment of long bone of large bird, probably Swan.

"72. Sesamoid bone of —— ?

"77. Fragment of vertebra, perhaps of Bear."

It is an interesting point, if we could make it out, what is the age of these bones. Are they the remains of animals who died upon the moraine rubbish before the talus was of sufficient thickness to form a recognizable bed? or are they bones washed out of the edges of the older cave-earth then exposed above the boulders? The bone doubtfully referred to Wild Swan would seem to point to a rigorous or temperate* climate. The bone doubtfully referred to Elephant does not give very strong indications. There seems a possibility of its having been washed out of the lower cave-earth, which contains Elephant-remains.

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* I have heard of three instances of Wild Swans having been shot in the immediate neighbourhood. C. Leigh, in his 'Nat. Hist. of Lancashire' &c., published in 1700, says, "Swans are common in these parts, but more particularly on the sea-coasts" (p. 141).

Most probably both of these sources contributed to this deposit of bones; but that the greater part of them are washed out of the lower cave-earth seems likely, for this reason—that not any fragments of bone were found through the 19 feet of talus which lies between the Neolithic layer and the top of the boulders.

Work in Chamber D. New Galleries.—Besides the work which has been done towards unfolding the glacial evidence at the mouth of the cave, a considerable amount of work has been done in excavating chamber D, and we have the result in a magnificent series of bones. Chamber D will be remembered by those who made a thorough visit to the cave, and explored all its narrowest recesses, as a very low chamber to the right of the principal entrance, filled nearly up to the roof with soft wet mud. It was so low over a greater part of its extent that progression could not be effected on hands and knees, and a serpent-like movement through pools of water lying on soft mud was the only way in which it could be visited. Chamber D now presents a very different aspect. So extensive have been the workings there, that at the entrance the ceiling is now 20 feet above one's head, and it gradually declines towards the inner extremity to a height of 4 or 5 feet. It is about 20 feet wide and 110 feet long; and two galleries have been discovered leading off from it on the right. One is blocked at the entrance with thick beds of stalagmite and fallen blocks of limestone, and has not been explored hitherto. The other leads down at Parallel 44 into a chamber 44 feet long with a N.E. direction, at a tolerably rapid gradient of about 1 in 4·5. At the end of this is a narrow squeeze which admits your Reporter for a short distance only. The forbidden ground beyond has been visited by Mr. John Birkbeck, Jun.; and he reports that this pipe-like cavity proceeds a short distance further and crosses a narrow chasm about 20 feet deep, down which he descended; but further progress proved impracticable.

This gallery we propose to call the Birkbeck Gallery, in acknowledgment of the energetic and valuable assistance of Messrs. John Birkbeck, Sen. and Jun., to the cave exploration from its commencement in 1870.

The Remains found in Chamber D.—The Committee is much indebted to Prof. Busk for his kindness in determining the bones found.

Before being submitted to him they have been all marked with register numbers* in the form of a fraction, the numerator (in this case 1) standing for the year (1874), and the denominator for the no. of the "find" in the year thus, $\frac{1}{1}$, $\frac{1}{2}$, $\frac{1}{3}$, &c. For 1875 the numerator is 2, and for 1876 it will be 3 if the explorations continue, and so on. As records are kept of what portion of the cave is explored in each year, this system will facilitate the reference of any particular bone to its position in the cave. In the past year the bones have also been marked with notes of their position. Thus the large skull of the Grisly Bear $\frac{1}{213}$ is marked "P 37, L 4·0, D 4·0," which means that it was found in the 2 feet Parallel 37, at a distance of 4 feet *left* of the wall of the chamber, and at a depth of 4 feet from the surface.

The note-book in which Prof. Busk's determination of the bones is written will be preserved in the Giggleswick Museum for reference.

His summary of the bones found in chamber D is as follows:—

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* This and other valuable services have been carefully carried out for the Committee by Mr. Jackson, the Superintendent.

"Out of about 209 specimens, including detached teeth,

127	belonged to	Bear,	
37	,,	Hyæna,	
36	,,	Bos,	
24	,,	Fox,	
22	,,	Deer	15 Red Deer, 7 Reindeer,
10	,,	Rhinoceros,	
2	,,	Horse,	
1	,,	Badger."	

To these we may add 1 of Pig, 2 of Elephant, and 1 of Hippopotamus.

The Elephant-remains consist of two small right and left lower antepenultimate milk-molars of *Elephas antiquus*, determined by Prof. Leith Adams. A fragment of the tusk of a Hippopotamus, about 2 inches long, is a discovery of the year, being the first relic of Hippopotamus found throughout the explorations. It was in Parallel 32, at a depth of 7 feet. Close by it was the carnassial tooth of a Hyæna, which perhaps may account for its having been found at such a distance from the river, now flowing about 1000 feet below.

It may be well here to correct an error as to the identification of remains of which a list occurs in Mr. Denny's paper "On the Geological and Archæological Contents of the Victoria and Dowkabottom Caves in Craven," Proc. Geol. and Polytechnic Soc. of the West Riding, 1859. At the head of the list of animals found is the following entry:—

"Cave Tiger (*Felis spelæa*). A canine tooth recognized by the late Dr. Buckland, and now in the British Museum.—Victoria Cave."

Inasmuch as in the course of six years' diggings no remains of Tiger or Lion had been recognized by the Committee, Mr. William Davies, of the British Museum, was communicated with; and he kindly returned an answer that he had examined the remains in the British Museum, that it was a case, as surmised, of erroneous identification, and that the tooth in question was the canine of a Bear.

The existence of the Cave-Lion in the Victoria Cave remains therefore to be proved.

Prof. Busk remarks of the bones and teeth submitted to him:—"They are a remarkably interesting collection, especially in the Bears; and I think the larger of the two skulls is by far the finest specimen of the kind yet found in this country."

Many interesting facts come out from the systematic record of the position of the bones. The appended Table (p. 174) of instances of bones which appear to belong to the same individual, but which have been found apart from one another, is an interesting commentary upon the way in which bones become scattered through a cave whether by the intentional transportation by beasts of prey in the process of devouring, or by the shuffling tread of the same beasts amongst the loose bones lying on the floor.

This leads us to the fact that many of the bones have a very fine polish; and it seems probable that the cause of this is that suggested by Dr. Buckland*, the treading of the beasts upon them; the fine mud occurring in the cave would make a very good polishing-paste, and being of a very plastic nature, would tend afterwards, when accumulating in sufficient quantity, to cover up the bones and preserve that polish. It occurs on the long bones of both ruminants and Bears, and not only on one side as noticed by Dr. Buckland, but all round. The specimens noticed are all apparently in the upper bed, to be hereafter mentioned. One of the polished long bones of an Ox has a crust of stalagmite upon it, and the polish runs up to and under it.

The greatest distance to which we have traced separate bones of the same individual is 44 feet in the case of the right calcaneum and right astragalus of a Hyæna; they occurred at the depths of 10 and 6 feet respectively.

Another interesting case is that of a magnificent pair of Reindeer-antlers, which were in four portions scattered over a distance of 32 feet. Moreover, and this is an instructive fact, the several portions were in different states of preservation, yet could be fitted together without any difficulty. This we should do well to remember when inclined to speculate on the relative age of bones from their state of preservation.

Again, the two fibulæ of Bear, probably belonging to the same individual, being a right and left, and having each a tumour of the bone in the same position on the shaft, remind us that bears may have sources of discomfort quite apart from the "res angusta domi." Two fearfully swollen and distorted metatarsals of the same animal ($\frac{1}{19}$* and $\frac{1}{50}$*) tell the same tale. On the other hand, two large tusks of the Grisly Bear ($\frac{1}{67}$ and $\frac{1}{68}$), worn down almost to their sockets, would seem to indicate a healthy life extending to a good old age.

Your Reporter has carefully reduced from the data in the register a synoptical section, showing the occurrence of each animal in the different parallels and the depth at which they occur. The result is a Table too bulky for publication, but its substance may be briefly given in words.

The bones appear to group themselves chiefly along two horizons, which are separated from one another by a greater or less thickness of cave-earth, laminated clay, and stalagmite.

The lower extends from the back of the boulder-beds before the cave mouth, is continuous with that which contained the human fibula, and runs almost continuously as far as P 42, and possibly further. The upper bed commences only at P 15, and extends to about P 43. Where the upper bed commences, the two horizons are about 12 feet from one another; but the lower rises quickly towards P 23, then continues horizontally at a depth of about 5 feet below the upper bed as far as P 35. At this point it rises still more, and the two beds not only touch each other, but seem to be somewhat intermingled.

The following Table shows the species occurring in the two beds in Chamber D:—

	Man.	Hyæna.	Fox	Grisly Bear	Brown Bear.	Badger.	*Elephas antiquus.*	Horse.	*Rhinoceros leptorhinus.*	Hippopotamus.	Pig.	Red Deer.	Reindeer	*Bos primigenius.*	Goat or Sheep.
Upper Bed	*	..	*	*	..	*	....	*	....	....	*	*	*	?	*
Lower Bed	*	*	*	*	*		*	..	*	*	..	*	..	*	

Peculiar to Upper Bed.
Badger.
Horse.
Pig.
Reindeer.
Goat or Sheep?

Peculiar to Lower Bed.
Hyæna.
Brown Bear?
Elephas antiquus.
Rhinoceros leptorhinus.
Hippopotamus.
Bos primigenius?

Common to both.
Man.
Fox.
Grisly Bear.
Red Deer.

Of course further work may much alter these lists.

The upper bed probably contains remains from the Reindeer period to the present, those of later date being mixed up with the older in the mud at the surface. But as distinguished from the lower bed, the chief characteristics of the upper appear to be the presence of Reindeer, and the absence of Elephant, Rhinoceros, Hippopotamus, and Hyæna. It is true that by the register there appears to be one specimen (a molar tooth) of Reindeer in the lower bed. It is marked P 35, and as at a depth of 8 feet, which would place it in the lower bed. It seems that this may be possibly a clerical error, and that 8 inches would be the proper reading. The mere placing the stop before or after the numeral would make the difference; moreover there are Reindeer-remains in the same parallel at a depth of 1 foot, and in the next parallel at a depth of 8 *inches*. If it was really found at a depth of 8 feet, it is a solitary instance of Reindeer in the lower bed, whereas in the upper it is common.

Of Hyæna, *very* common in the lower bed, there appears at first sight to be one specimen (a humerus) in the upper; but on examination this is not quite so certain. It occurs in Parallel 37 at a depth of 2 feet, where the two beds run together. This alone ought to put us on our guard. But strangely enough it is at 2 feet higher elevation in the same parallel than the great skull of Grisly Bear, which is proved by the situation of its lower jaw on the surface to belong to the upper bed. It did not lie, however, immediately above the Bear's skull, but 2 feet east of it; so that it seems quite possible that the apparent superposition may be only due to the unevenness of the floor at the time when the Bear's skull came into position.

It is also highly improbable that had the Hyæna lived at the same time as this great Bear, he would have left so fine a skull intact for the Committee to exhume.

These facts are of great interest and importance, as warning us against the danger of assuming from the juxtaposition of objects their contemporaneity in all cases. In this case we have a fauna which we may confidently assign to a cold climate, separated in some parts by an accumulation of deposits *twelve feet in thickness* from an earlier one, which is equally characteristic of high temperatures; whereas in another part of the cave not far off, where the material to separate them is wanting, we have animals from icy and tropical countries intermingled in a confusion which would be puzzling did we not get the clue hard by. It is evident that here the separation is natural and regular; the mixture is abnormal and accidental.

It is probable that Brown Bear occurs in both the beds; there are many Bear-remains in both; but they do not, in most cases, admit of specific determination. Brown Bear has been found before in the higher beds in other parts of the cave.

Rhinoceros leptorhinus has not been found before in the cave, but its presence is well established now by teeth and bones*. It is interesting to note that it is as usual accompanied by *Elephas antiquus*. Hippopotamus, as already stated, has been found this year for the first time.

In the upper bed, the only sign of man's presence consists of the spinous process of a bear's vertebra, which has been hacked, apparently by some cutting-instrument with a tolerably regular edge. It might have been done with a bronze celt or a polished flint axe. It is probable that chamber D was never the resort of man within the historic period. The soft wet mud of the floor and the lowness of the roof render it most unlikely that any one would take to it, except under the direst necessity or in the pursuit of science.

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* P.S. It would appear that the remains occurring in the Cave, formerly attributed to *R. tichorhinus*, really belong to this species.

In the lower bed, again, evidence of man's presence is but scanty. At the mouth, and close to where the human fibula was found, we have this year met with a piece of rib ($\frac{2}{135}$) apparently nicked by human agency. It is about 2½ inches of the dorsal end, but the articulating surfaces are broken off. There are nine transverse nicks not reaching quite across, some not halfway, and also a longitudinal nick. They appear to have been made by some clumsy instrument drawn backwards and forwards. In character they are totally unlike the square troughed hollows made by the gnawing of rodents; and they are equally unlike the furrows heavily ploughed by the teeth of Carnivores. This specimen was at a depth of 25 feet from the roof of the cave, which at this point was filled to the ceiling. We cannot at present say of what animal it is a rib. Some light may perhaps be thrown on it by a careful comparison. This is immaterial compared to the main fact, which is, that there is much difficulty in supposing it to have been nicked by any agency other than human.

Conclusion.—And now, having restricted ourselves almost entirely to the hard road of fact, in conclusion we may perhaps be permitted to indulge in a short flight of fancy. Let us endeavour to realize how great is the distance in time which separates the savage of Craven from our own day. We have the history of much of it in the Victoria Cave itself, and we may restore some of the missing pages from the surrounding district. At the Cave, Roman times are separated from our own by sometimes less than one, but not by more than two feet of talus, the chips which time detaches from the cliffs above. The Neolithic age, which antiquaries know was a considerable time before the Roman occupation, is represented by a layer in some places 4 or 5 feet beneath the Roman, in others running into it. Then comes a thickness of 19 *feet* of talus without a record of any living thing. Judging by the shallowness of the Roman layer, this must represent an enormous interval of time. And this takes us down to the boulders, the inscribed records of the Glacial Period. They must represent a long series of climatal changes, during which the ice was waxing and waning, advancing and melting back over the mouth of the Victoria Cave. This period saw the Reindeer and the Grisly Bear occasionally in possession. Then we have an unconformity, a break in the continuity of the deposits, the boulders lying on the edges of the older beds—Time again! And that time was long enough for changes to take place which allowed the district to cool down from a warmth suitable to the Hippopotamus and become a fitting pasture-ground for the Reindeer. It was in that warm period that the Craven savage lived and died.

But these are not all the changes which occurred in the north of England since that time. The age of the great submergence represented by the sea-beaches of Moel Tryfaen and Macclesfield, and by the Middle-Sands-and-Gravels of Lancashire, has left no record up at the cave. Your Reporter is of opinion that the submergence did not attain in that district a greater depth than six or seven hundred feet; and this would still leave the cave 700 feet above the sea, though it would cut up the land into a group of islands. The fact is sufficient for us, the depth is immaterial. Upon no fact are geologists better agreed than upon the existence of a widespread submergence and emergence of land towards the close of the Glacial Period. No tradition is common to more races or religions than that of a great deluge. Where back in the past is the common point whence these two far-travelled, almost parallel rays of truth had their origin? In the opinion of your Reporter the Craven savage, who lived before the Great Ice-sheet and *before the Great Submergence*, may form another of the many strong ties which bind together the sciences of Geology and Anthropology.

APPENDIX.

Table of Remains which fit, pair, or otherwise indicate their belonging to the same individual, with the distances at which they were found apart.

Register Number.	2-feet Parallel.	Distance left of right wall of Chamber D.	Depth from surface.	Nature of the Bones.	Extreme distances apart in feet.
$\frac{1}{5}$	18	12·0	1·6	Radius of large Fox } correspond ?	12
$\frac{1}{17}$	24	16·4	2·0	Femur " "	
$\frac{1}{20}$	26	9·2	5·3	Atlas of Bear } fit	22
$\frac{1}{213}$	37	4·0	4·0	Skull of large Grisly Bear	
$\frac{1}{41}$	33	2·0	·10	† Right ramus of mandible of ditto	
$\frac{1}{24}$	27	10·3	2·0	Right scapula, Bear } pair } correspond ?	6 or 36
$\frac{1}{139}$	30	·4	·6	Left " "	
$\frac{1}{258}$	45	·6	1·3	Pelvis of very large Bear	
$\frac{1}{28}$	28	12·0	2·0	Left femur of young Bovine } pair	8
$\frac{1}{39}$	32	17·0	·6	Right " "	
$\frac{1}{43}$	36	4·0	7·0	Fibula of Bear with tumour } pair	10
$\frac{1}{37}$	31	1·0	7·0	" " "	
$\frac{1}{90}$*	15	7·0	10·0	Right calcaneum, Hyæna } fit	44
$\frac{1}{222}$*	37	16·0	6·0	Right astragalus, "	
$\frac{1}{94}$	16	......	12·0	Right pisiforme of large *Cervus* } pair	12
$\frac{1}{108}$	22	4·0	9·0	Left " "	
$\frac{1}{135}$	28	9·0	7·0	Calcaneum of large Bovine } fit	34
$\frac{1}{101}$	18	7·0	10·0	Left naviculare, *Bos primigenius*	
$\frac{1}{182}$	35	5·6	8·0	" astragalus, "	
$\frac{1}{117}$	24	4·0	9·0	Right ulna, Hyæna } pair	3
$\frac{1}{118}$	24	7·0	9·0	Radius, "	
$\frac{1}{132}$	27	3·0	1·0	Different portions of a magnificent pair of Reindeer-antlers } ...	32
$\frac{1}{205}$	36	2·0	·8		
$\frac{1}{242}$	14	1·0	1·8		
$\frac{1}{256}$	43	1·0	1·0		
$\frac{1}{192}$	35	9·0	5·0	Right os magnum of Red Deer } fit.....	5
$\frac{1}{194}$	35	4·0	5·0	" unciforme "	
$\frac{1}{199}$	35	·6	·6	Left lower jaw, Fox } fit..............................	16
$\frac{1}{253}$	43	1·3	1·6	Right " "	
$\frac{1}{9}$	20	13·0	2·0	Left scapho-lunar, Bear } fit.........................	32
$\frac{1}{212}$	36	3·0	5·0	" os magnum, "	

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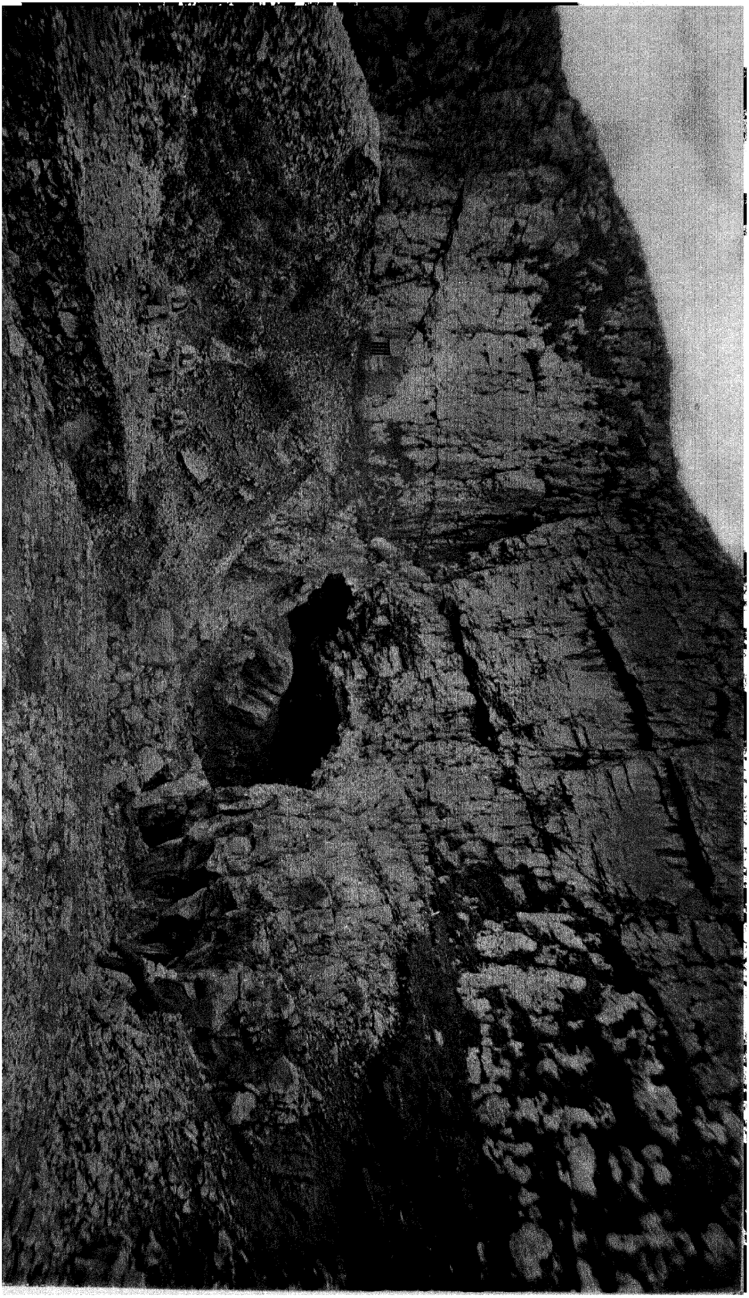
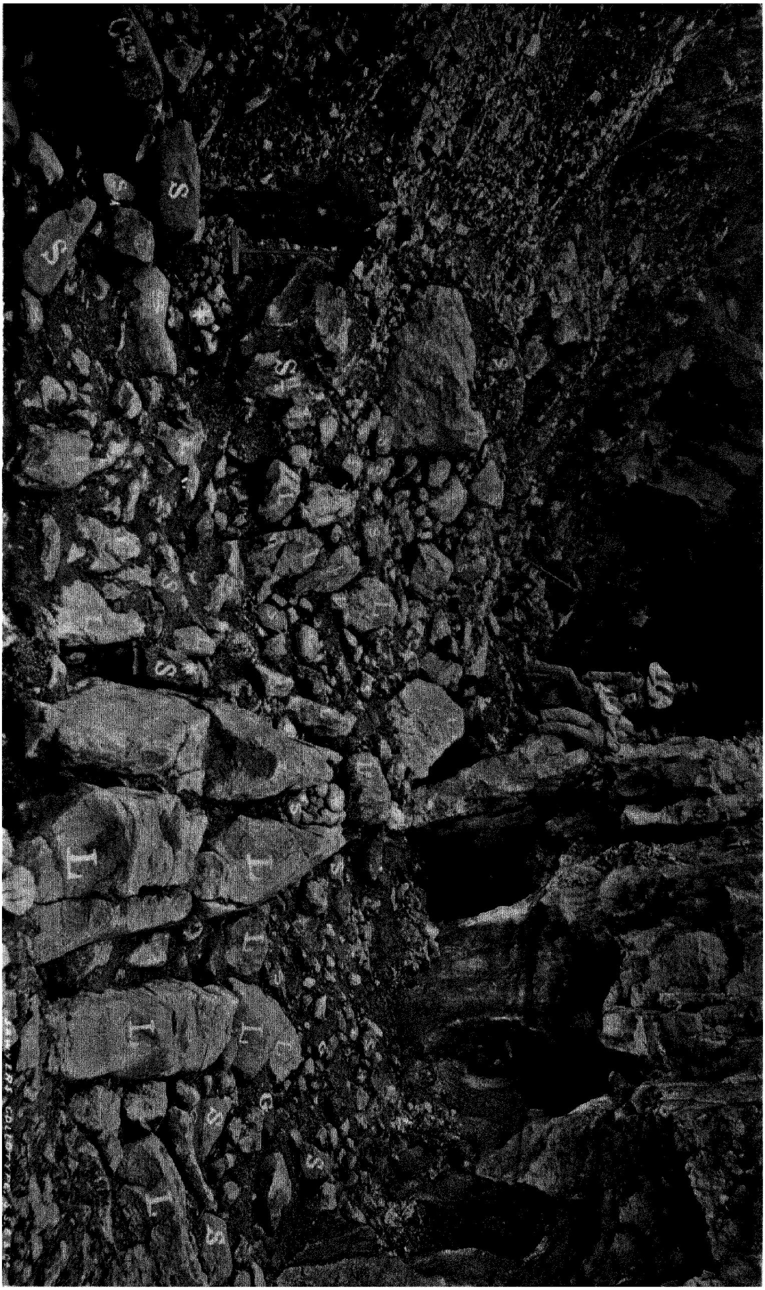
† The left ramus was already in the Giggleswick Museum, and had been found in another part of the Cave.

Plate V.



THE VICTORIA CAVE SETTLE No. 1.

Plate VI.



THE VICTORIA CAVE, SETTLE; Nº II.

EXPLANATION OF THE PLATES.

Plate V.

Victoria Cave, No. 1. This gives a general view of the Cave and the cliffs above. Above the workmen is a cave boarded up and used as a tool-house. To the right of that is a niche in the Cliff, the old entrance to the Cave first discovered by Mr. Jackson. The present entrance, before the excavations, was completely covered up with screes. Mr. Jackson, the figure on the right, is sitting close to the arched niches mentioned at p. 167. The flat in the fore ground is not a natural feature, but produced by the levelling of the tip and talus. The bottom of the valley is at a far lower level. A level cutting through the flat is seen going from the left-hand lower corner up to the boulders.

Plate VI.

Victoria Cave, No. 2, gives a nearer view of the boulders near the entrance, of the rock-pinnacles forming the floor, and of the arched niches described at p. 167. The human relics were found near the crowbar, which is seen in the background beyond the workmen, but at a lower level Mr. Jackson is standing between the boulders and the talus, and the marked difference between the two deposits is well seen. The boulders before being photographed were marked S for Silurian, L for Carboniferous Limestone, and G for Carboniferous Gritstone. The marks C^{on} and S^{tl} should have been C^{te} and S^{te} for Conglomerate and Stalactite, and denote respectively a piece of the conglomerate from the base of the Carboniferous Limestone, and two large pieces of Stalactite, which have apparently fallen on the boulders from the roof of the Cave before it had been worn as far back as it now is.

On the River Avon (Bristol): its Drainage-Area, Tidal Phenomena, and Dock Works. By Thomas Howard, *M.Inst.C.E.*

[A communication ordered by the General Committee to be printed *in extenso*.]

[Plate VII.]

The head-waters of the Bristol Avon may be considered to take their rise in the eastern slopes of the lower Cotswolds, to the north of Tetbury in Gloucestershire, the stream gathering in from the west, in its course southward through Malmesbury, the drainage of the oolitic district about Badminton; while the watershed on the east is only parted by a slight ridge from the country draining into the uppermost branches of the Thames. Below this the Avon drains the Wootton-Bassett district, together with the country bounded by the western outcrop of the chalk hills of Marlborough, Avebury, and Beckhampton Downs, and the north-western part of Salisbury Plain, including the towns of Calne, Devizes, Melksham, Westbury, Trowbridge, and Bradford-on-Avon. An important tributary, the Frome (Somersetshire), which brings the most southerly part of the drainage of the Avon, rises near Bruton, and, embracing the watershed of the easternmost part of the Mendip Hills, drains the town of Frome and several important manufacturing villages, joining the Avon at about three miles below Bradford. Below this the Avon receives on the left the Midford Brook, and on the right the Box and other streams; and flowing on through Bath, receives several small affluents, and at Keynsham the Chew, which springs from the northern slope of the Mendips. In this district the springs from which Bristol is supplied with water take their rise, at Chewton Mendip. Continuing its course towards Bristol, the river falls into the tideway over a weir at Netham, a point about 3¾ miles above the entrance to the docks at

Bristol. The tidal portion of the river continues its course by a new channel, cut about seventy years ago south of the city, to its junction with the Severn estuary at Kingroad. The fresh water of the river, impounded by the dam at Netham, is diverted by a canal into the heart of the city, passing under Bristol Bridge through what was formerly the old course of the river, but now converted into the Bristol floating harbour. Into the harbour enters also another affluent, the Frome (Gloucestershire), taking its rise in the hills above Wickwar and Chipping Sodbury. The docks at Bristol have therefore the advantage, in short-water seasons, of the combined volume of these streams, which, after passing through the harbour, is discharged at the various outlets of the locks and basins.

The entire drainage-area of the Avon and its tributaries above Netham is about 795 square miles, and that of the Gloucestershire Frome about 68 square miles, making the total area draining in through Bristol Harbour about 863 square miles. Between Bristol and the mouth of the river the area draining into the Avon is very limited, amounting only to about 31½ square miles, the chief drainage of this part of the district being direct into the Severn.

The longest branch of the Avon, from its rise above Tetbury to Bath city bridge, is, taking its winding course, about 46 miles. The navigable part of the river from Bath to Netham is about 14¾ miles, and the tidal portion from Netham to the junction with the Severn about 11 miles. Total length about 72 miles.

The fall in the bed of the Avon from Bath to the Severn is as follows, viz.:—

	Distance			Fall.	Average rate of fall.
	m.	f.	chs.	feet.	
From Bath Bridge to tail of Netham Dam	14	5	0	39·94	1 in 1934
Tail of Netham Dam to opposite Cumberland Basin	3	6	7	15·63	1 in 1298
Cumberland Basin to junction of Avon and Severn at low water	7	0	1	19·30	1 in 1918
	25	3	8	74·87	

Between Bath and Netham Dam there are several weirs for impounding the water for mills and for navigation purposes.

The very interesting geological features of the district around Bristol will probably be dealt with in some other Section of the present Meeting; but it may be within the scope of this paper just to remark that there are few rivers of the size of the Avon which embrace in their drainage-areas so great a geological range. Every formation from the Old Red Sandstone to the Upper Greensand and Chalk inclusive will be found within its watershed. About two thirds of the whole consists of the various strata of the Oolitic system, while the remaining one third is made up of a small area of Chalk with the Greensand formations on the east, and on the west chiefly Lias, together with the formations below it down to the Old Red Sandstone.

Although there are no mountainous elevations in the drainage-area of the Avon, the greater part of the country is of a hilly character. The general average elevation of the upper part of the watershed may be taken as about 300 feet above mean sea-level; but there will be found many outliers of the great and inferior oolites rising from 600 to 700 feet. The hills of greatest elevation will, however, be found in the Frome (Wiltshire) district, where the Old Red Sandstone, at Downhead Common (Mendips), reaches 1078 feet; the Inferior Oolite, at East Cranmore, 814 feet; the Mountain Limestone, at Leigh-upon-Mendip, 800 feet; and the Coal-measures above Mells about 770 feet. The Inferior Oolite at Lansdown, near Bath, also rises to about 720 feet, and at Dundry, south of Bristol, to about 750 feet.

The hilly and non-absorbent character of the soils of a great portion of the district causes the rain which falls to be carried off rapidly; and heavy floods are sometimes experienced in Bristol, especially when the discharge of flood-waters, through the floating harbour, is impeded for a time by the rise of high spring-tides. The mean average annual rainfall in Bristol is about 32½ inches. This amount is increased on the slopes of the Cotswold and Mendip Hills, on the latter of which it averages about 47 inches; but the mean of the whole district would perhaps not be greatly different from that at Bristol, when the lessened quantity, falling on the eastern part of the drainage-area, is taken into calculation.

In considering the tides of the Avon, it may be desirable for a moment to refer to the special tidal phenomena of the Bristol Channel and Severn estuary. The crest of the free tidal wave of the ocean, which in the deep waters of the Atlantic rolls forward the high-water line at a rate of probably not less than about 500 miles an hour, enters the English and Irish Channels with a gradually decreasing velocity, owing to the resistance from the seas becoming more shoal; and this retardation is further increased in the Bristol Channel by the converging lines of its shores. The whole of the appreciable tide in the estuary of the Severn is due to the momentum of the wave originated in the deep waters of the open ocean. One important result of these conditions is, that as increased resistance is met, so the wave is forced higher and the tidal range magnified; and while the rate of progress of the crest of the wave is much diminished, the actual movement of the particles of water to and fro, in flood and ebb, becomes more rapid owing to the greater rise and fall. We have thus a great range of tide in the Severn and the Avon with a considerable velocity, especially in the narrow and deep parts of the former river.

As evidence of the retarded advance of the crest of the tide-wave and the increased range of tide spoken of in the Bristol Channel, we may take the case of an ordinary spring-tide, which, advancing in from the Atlantic, brings high water off the Scilly Islands at $4^h\ 30^m$ o'clock, with a rise of tide of 16 feet above mean low-water springs at that point. This crest of high water will reach Lundy, a distance of 140 miles, at $5^h\ 15^m$, where the rise will be 27 feet; Nash Point, 49 miles from Lundy, at $6^h\ 25^m$, with a rise of 33 feet; Cardiff, 24 miles from Nash Point, at $6^h\ 56^m$, with a rise of 37½ feet; Kingroad (mouth of the Avon), 16 miles from Cardiff, at $7^h\ 13^m$, with a rise of 40 feet; and Sharpness, 18½ miles above Kingroad, at $7^h\ 58^m$, with a rise of 25 feet, this latter above Ordnance datum, or an absolute height of about 2 feet 4 inches above high water at Kingroad, the total range at Sharpness being less than at Kingroad, on account of the great slope of the bed of the river. At Framilode, about 13 miles above Sharpness, the effect of the gorging up of the tide has attained its maximum, and the tide flowing up the remaining distance to Gloucester is due entirely to the acquired momentum. At Gloucester the further flow upwards is stopped at ordinary tides by weirs recently erected, although the top of equinoctial springs flows over them.

The total range of tides at the mouth of the Avon, and the great difference between neaps and springs, are shown on a diagram plotted from observations made continuously for a fortnight. In this diagram (Plate VII. fig. 1) the actual heights of high and low water of each tide are plotted above or below Ordnance datum, and then two equalizing lines, drawn as a mean of the observations, serve to show what would be the high or low water for any given range of tide from 15 up to 46 feet.

The same diagram shows also how far the mean half-tide level at the mouth of the Avon agrees with the theoretical mean sea-level, as adopted for the Ordnance datum. The half height of each range of tide, taken in the above-mentioned observations, is plotted, and a mean equalizing line drawn between them. The result shows that at lowest neaps the half-tide level is bout 3¾ inches below, and at highest springs rises to about 1 foot 8 inches above Ordnance datum. Other observations made at the mouth of the Avon tend to confirm the conclusion that, so far as regards our local tides, the mean half-tide is not a fixed level, and that it is above the Ordnance datum. This may point to the probability that the mouth of the Avon is somewhat within the influence of the surface fall of the lowest part of the Severn, and above the true level of ocean low water.

In connexion with the subject of mean sea-level, it may not be uninteresting to notice that, at the time of the last Meeting of the British Association at Bristol, in 1836, the question was much under general discussion, and it was resolved that a series of levels should be taken between the Severn at Portishead and Axmouth on the English Channel. These were undertaken and carried out by the late Mr. T. G. Bunt in 1837, and were conducted with an amount of care and skill to secure accuracy which has seldom been exceeded. In connexion with the stations levelled to at either end of this line, a series of simultaneous tidal observations were made, by which it was found that the sea at Portishead rose at high water 13 feet 7 inches higher, and fell at low water 12 feet 2 inches lower than at Axmouth, the total difference in the ranges of the same tide at the two places being as much as 25 feet 9 inches. This is a very striking illustration of the effect of the momentum of the incoming tide-wave heaping up the water in this funnel-shaped estuary.

On looking at the map it will be seen that the course of the Avon lies at about right angles to that of the Severn; and its tide may be considered to be generated, as it were, by the passing tide of the Severn, rather than directly due to the momentum of the original tide-wave. As the flood-tide rises in Kingroad it pours into the Avon, and a current is established in the latter river which soon obtains a momentum of its own. The effect of this is very plainly seen, and serves to illustrate the same phenomena of engorgement which takes place on a larger scale in the Bristol Channel, for the tide rises to a higher level in the Avon the further we go up the river. Taking the flood of an equinoctial spring-tide, we find that at the mouth of the Avon high water rises to 24 feet 10 inches, at Sea Mills to 25 feet 3 inches, at Cumberland Basin to 25 feet 5 inches, at Netham Dam to 25 feet 9 inches, and finds its summit at a point about six miles above Cumberland Basin, where it rises to 26 feet 4 inches, all above Ordnance datum. Here the momentum, as we have seen in the case of the Severn, becomes spent, and the rest of the tide has a reversed slope up the freshwater river to Hanham, where its level is only 26 feet above datum.

On the longitudinal section of the Avon exhibited, the points above mentioned are shown, as also some cross sections of the river, the slope of the bed, lines of the ordinary run of low water, and lines of spring and neap tides. The crest of the dam at Netham is 19·78 feet above Ordnance datum, and is the level at which the floating harbour of Bristol is maintained. All tides above this level flow over the dam up towards Hanham and Keynsham.

Another diagram of tidal observations, taken simultaneously for a fortnight at the mouth of the Avon and at Cumberland Basin, shows the relative heights and times of the tides at these stations through a complete range of springs and neaps. It will be seen that the level of high water at Cumberland Basin is, on an average, about 7 inches higher than at the mouth of the river. We also find that, as regards time, high water at Cumberland Basin is about the same as at Kingroad. High-water equinoctial springs is, however, at Netham about a quarter of an hour, and at Hanham half an hour later than at Cumberland Basin.

Connected with this part of the subject is the duration of flood and ebb, and the rate of rise and fall of tide at Kingroad. The general result of our observations shows that, at extreme low neaps, the flood is longer than the ebb by about one hour; but that, as the tides increase in range, the duration of ebb becomes progressively longer than flood, till at the highest equinoctial springs the tide rises from low to high water in 4 hours 45 minutes, and takes about 7 hours 30 minutes to ebb. A reference to the diagram (Plate VII. fig. 2) will show the rate, hour by hour, of rise and fall at the mouth of the Avon for a low neap and a high equinoctial spring-tide. The rapid rate of rise of the spring-tide is remarkable, being 11 feet 11 inches in the second hour, and 12 feet 4 inches in the third hour of flood.

The velocity of run of tide is not great in the Avon, the highest rate, from observations taken at spring-tides in the river $1\frac{3}{4}$ mile below Cumberland Basin, hardly reaching 3 miles an hour. In the Severn at Kingroad the velocity on half-flood at high spring-tides comes up to about 6 miles, and at half-ebb to about $4\frac{1}{2}$ miles an hour.

Amongst other diagrams connected with the tides will be found some which show simultaneous observations of a low neap, and the highest spring this year at Cardiff, Portishead, Avonmouth, Bristol, and Sharpness, kindly taken by the engineers of the docks at these several places (fig. 3).

One important though unwelcome feature connected with the tides of the Avon is the enormous quantity of mud held in suspension in the water. With the exception of the Humber, there is probably no river in England that in this respect will compare with it. This part of the subject is one not merely of scientific interest, but of practical economical importance; for it is necessary that its effect should be taken into consideration in all questions of dock construction or maintenance in this district. From many observations made to ascertain the average amount of mud held in suspension in the water in the river, it is found that, from any given volume of the tide-water, there will be a deposit of about $\frac{1}{376}$th part of mud, which becomes, under superimposed layers, soon converted into stiff silt. In the Severn the quantity, though very considerable, is less than in the Avon.

The general character of this mud is somewhat different from that of the alluvial deposit which forms the banks of the river Avon and the adjacent flat lands bordering on the Severn. This alluvium is generally found to consist of several feet of stiff brown clay, or brick-earth, underneath the top soil, below which is a thick bed of bluish silt, containing much very fine quicksand and with but little clay. Below this again is almost invariably found a bed of coarse gravel, with frequent fossil remains of red deer, horse, and ox (*Bos longifrons* and *Bos primigenius*). The level of the surface is very uniform over the whole district, and is below high water of equinoctial spring-tides, the country, where exposed to the overflow of the tides, being protected by an ordinary sea-bank of from 3 to 5 feet high. The flat margin of grass land between the sea-bank and the edge of the water still continues to be raised above the level of the enclosed land by the deposit from very high tides.

The mud spoken of is of an exceedingly light character, borne up and down in suspension in the water as long as the mean velocity of ebb or flow does not fall much below about 2½ feet per second. Whenever from any cause the velocity is much reduced, the mud begins to form a deposit. An analysis of this silt, and also of the upper and lower strata of the alluvial bed through which the lower part of the Avon runs, has been kindly made by Mr. W. W. Stoddart, F.G.S., and is as follows:—

Top bed of Alluvium (Brown Clay).

	parts.
Clay	26·52
Sand with small quantity of mica	28·14
Carbonate of lime	15·11
Sulphate of lime	4·41
Protoxide and peroxide of iron	4·74
Salts of sodium, magnesium, &c.	1·65
Organic matter	4·15
Moisture	15·28
	100·00

Bottom bed (or *Blue Silt*).

Clay	3·55
Sand	31·71
Carbonate of lime	33·84
Sulphate of lime	4·69
Peroxide of iron	2·63
Soluble salts	1·29
Organic matter	2·64
Moisture	19·65
	100·00

Tidal mud of Avon, taken from recent deposit in "North Channel."

	parts.
Clay	22·48
Sand (viz. coarse 0·61, fine 1·04)	1·65
Carbonate of lime	22·27
Peroxide of iron	4·43
Soluble salts	5·29
Organic matter	2·13
Moisture	41·75
	100·00

A striking instance of the great amount of mud held in suspension in the tide-water of the Avon, and the readiness with which it will, under favourable conditions, deposit and form accretions, has been shown in the last few years at the mouth of the Avon. In the year 1852 the author assisted in making a very accurate survey of the depths of water at the junction of the Severn and Avon, and of the entrance-channels leading into the latter river. At that date, and indeed from time immemorial, the only available channel for shipping was the "North Channel," and there was then a depth of water of from 6 to 10 feet at low water spring-tides. The other channel, the "Swashway," was gradually becoming used by small craft when the tide was in, but there was no low-water channel through it. The depth of the "North Channel" was good up to 1865, when the Irish and other steamers used to land their passengers there. Even in October 1867, Capt. Bedford, R.N., who was surveying the roadstead, says he "found 42 feet of water in this channel, but that in 1871 he only found 8 feet, showing an accumulation of 34 feet, or at the rate of 9¾ inches a month."

On a plan accompanying this paper (Plate VII.) is shown a survey made of the entrances to the Avon in 1852, and another made in 1875, together with sections taken across the "North Channel" at these dates. In these sections the extent of silting up is shown; and calculations made therefrom give a quantity of over a million cube yards of mud deposited here within the last ten years. The top of spring-tide still flows over the surface and adds to the deposit, but at neap-tides the new ground can be safely walked across. The greatest depth of the silting up is about 41 feet above the bed of the river in 1852.

The foregoing remarks on the watershed and on the recorded observations of the tides of the Avon will, it is hoped, have served to give a general knowledge of the natural conditions and capabilities of the river. It remains only necessary to show briefly what has been, from time to time, done in the way of providing for or improving the accommodation for vessels frequenting the port.

Up to about the middle of the last century the shipowners of Bristol seem to have been content with the accommodation the tide (then flowing and ebbing through the centre of the city) gave them. Vessels were then comparatively small, and of a build adapted to lay aground at low water. From the year 1765 to 1800, however, various schemes, including amongst others designs from Smeaton, Ralph Walker, Josias and William Jessop, were brought forward for providing floating dock accommodation, ending ultimately in the carrying out of a plan by William Jessop. This design took possession of those portions of the rivers Avon and Frome which ran through the city, converting them into the present floating harbour, and substituting a new channel for the tidal water of the Avon to the south of the city. This scheme was projected, carried out, and the docks held by a private company.

Looking at the character of the public works at that day, the construction of Jessop's works was a very spirited undertaking, and they afforded for a long time accommodation in advance of most other ports. But about the year 1830, when steam-vessels were beginning to take an important place and ships were growing in size, the inadequacy of the old lock entrances, and the difficulties of the navigation of the river, began to be seriously felt, and various schemes were brought forward to provide accommodation at Kingroad. Amongst other designs for this purpose was one for a stone pier by Mr. Mylne in 1832, and another by Sir J. MacNeill in 1839, and also one for a floating pier by the late Mr. I. K. Brunel in 1839. None of these, however, were carried out; and to the discontent felt at the want of adequate accommodation for the port soon began to be added the opinion that the high charges of the Dock Company tended still further to restrict the trade. Much local agitation ensued, ending in the transfer of the docks (in 1848) from the Company to the Corporation of Bristol. They at once resolved to make an alteration in one of their entrance-locks, so as to accommodate steamers of the 'Great Western' and 'Great Britain' class, built in Bristol. A new lock sufficiently wide to admit these was constructed, on the site of a smaller lock at Cumberland Basin, by the late Mr. Brunel. In this lock may be seen the earliest examples of lock-gates made in the form of caissons.

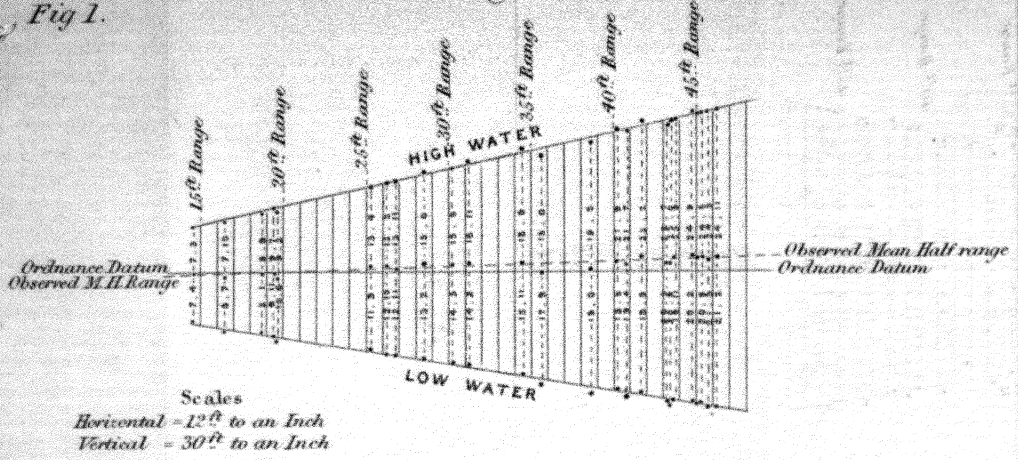
The first act of the Corporation, on taking over the docks, was to reduce the dues; and from this cause, as well as also partly from the port sharing in the general increase of trade throughout the country, the dock revenues began to amend. Just about the same time the dimensions of steamers were vastly increasing, and an increased desire was felt here that the port of Bristol should have accommodation for them. It was not so much a want of dock-space in the floating harbour that was felt, as the difficulties arising from the tortuous course of and want of depth in the river, and also the limits placed on the breadth of vessels by the lock entering the harbour. Some improvements were made in the river, and several schemes for more extensive alterations considered. Various designs for independent docks at Portishead and on the Gloucestershire side of the Avon were also brought forth, the one on the most extensive scale being by the late Mr. J. M. Rendel in 1852.

Amongst other modes proposed for providing for the largest class of ocean-going steamers was that of placing a dam, with suitable entrance-locks and works, at the mouth of the Avon, so as to form the channel of the river into an extension of the present floating harbour, entirely supplied with land-water, and having facilities for admitting ordinary vessels at almost all states of the tide. After long consideration of the subject, and making tidal and other observations bearing upon the question of its feasibility, the author laid before the Corporation, in 1859, the particulars of a design which he considered could be practically and safely carried out, and which, while it would have given to Bristol all she could need for any extension of trade, would not, in his opinion, have been detrimental to the navigation of the Severn estuary or to any national interest. Further, it was obvious that by keeping the whole of the trade of the port under one jurisdiction, with due responsibilities, means would have been available for affording that artificial aid to the maintenance of the roadstead, and for the regulation of a good channel through it, which successive surveys show to be increasingly desirable. These opinions have not been altered by more recent observations of the local conditions of the case, nor by an unprejudiced consideration of the various arguments which have been advanced against the idea.

In venturing to propose such a plan, full recognition was given to the general axiom, that the abstraction or suppression of the tidal water of an estuary or harbour is undesirable. But every case must be judged on its own merits; and investigation of this led to the conviction that it would not, as regards the Severn, be so much a case of abstraction as of partial restoration. It is probable that the momentum of the tidal wave, which we have in a former part of this paper seen coming up to Kingroad, would not be reduced nor the rise of tide there lessened, whether the consequent flow of the water were drawn off up the Avon, or left to flow on directly up the Severn. Moreover, it was held likely that this diversion, instead of bene-

Diagram shewing Ranges of Tides at Mouth of Avon.

Fig 1.



Scales
Horizontal = 12ft to an Inch
Vertical = 30ft to an Inch

Fig 2.

RATE OF RISE AND FALL OF TIDES AT MOUTH OF AVON

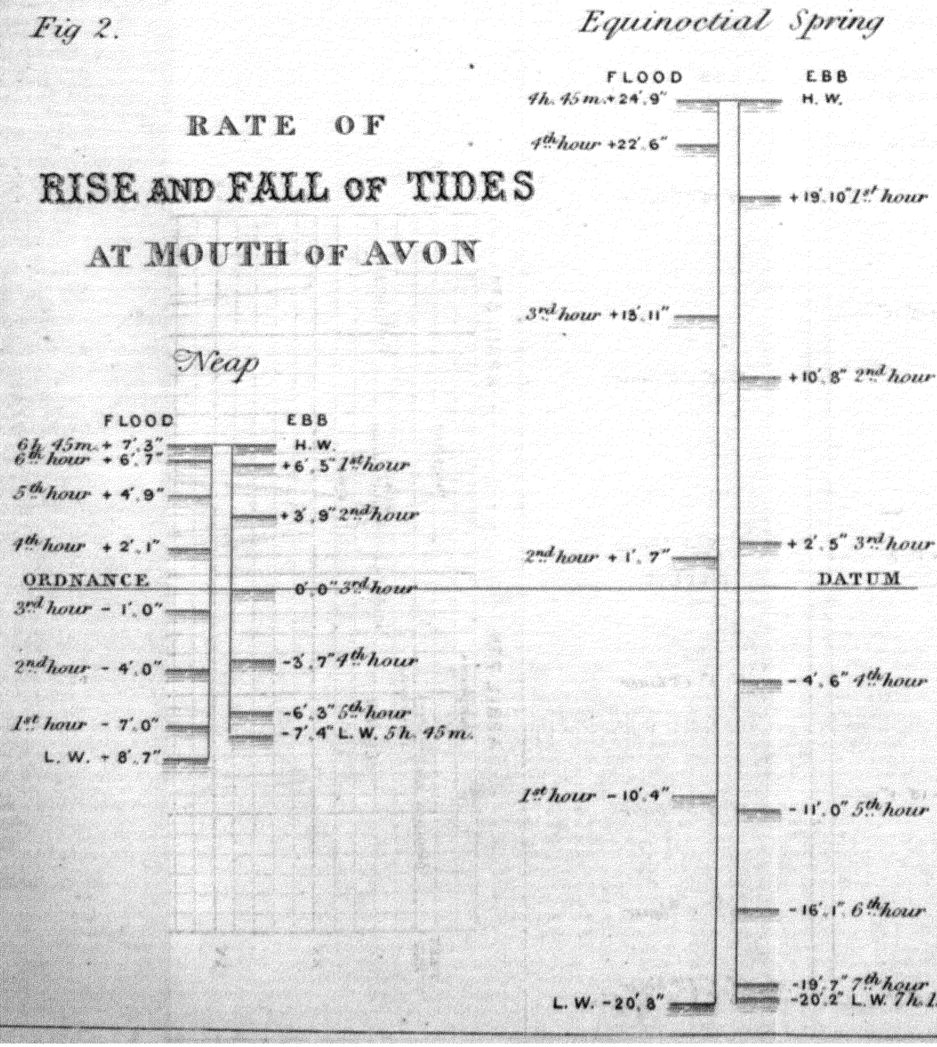
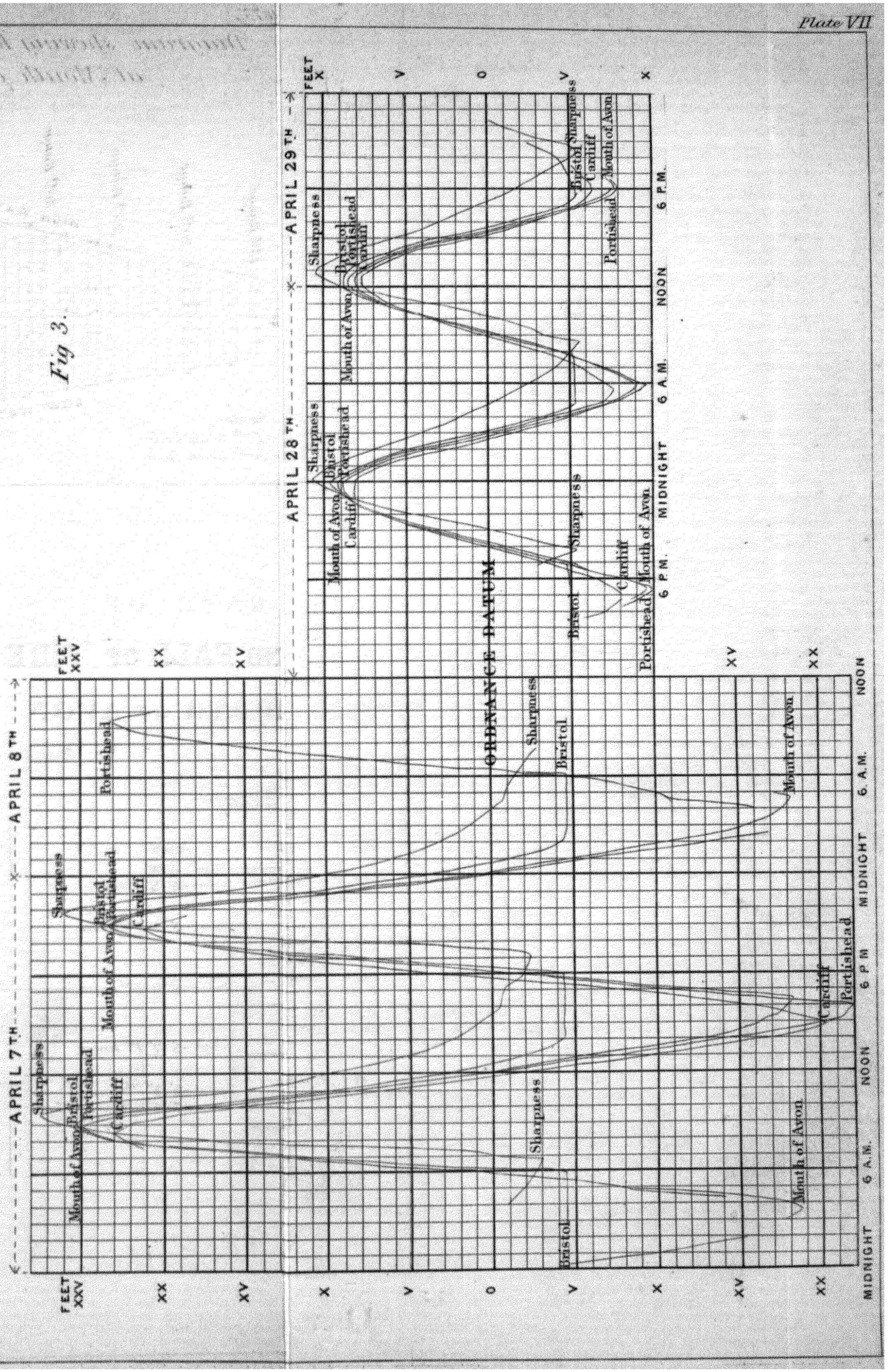


Fig 3.



fiting the anchorage, tends to lessen the power of the tide to keep open a good deep channel in the Severn. Examination of the soundings tends to confirm this opinion; there is an evident shoaling of the water in the Severn immediately above the mouth of the Avon.

The limits of this paper will not, however, permit the bringing forward all that might be said on this subject, or the opportunity of showing the natural as well as commercial requirements and facilities which the district afforded for carrying out such a work. The scheme received, for various reasons, considerable local opposition, and was ultimately left in abeyance. The great outlay (about £1,000,000) which has been recently, or will very shortly have been, made on dock-works connected with the Avon, and the separate vested interests which have consequently arisen, have placed serious financial difficulties in the way of its speedy revival.

Within the last few years the Corporation have, through the author, as their engineer, made many improvements in their existing dock-works. The old lock entrances, which were not adapted to the trade of the present day, have been supplemented by two new locks, of larger dimensions, laid at a deeper level than the old ones, and provided with all modern appliances of hydraulic and other machinery for quick work. It would be out of place to attempt to give here all the details of construction of these works. The ordinary and some special difficulties were met with and overcome. These chiefly arose from unsatisfactory foundations, and from having to work in confined spaces surrounded by water, portions of the wall of the approach to the outer entrance-lock requiring to be built in trenches on the river-bank, within the line of high water, at a depth of 53 feet. In the bottom of the lock excavations much trouble was experienced from springs of water from the gravel bursting up through the foundation level of the lock. These were overcome by building in at intervals along the lock inverts pipes reaching down into the gravel, each fitted at the top with a very light gun-metal valve, which, lifting easily with pressure from beneath when the tide is low, permits the water to escape, and closes again when the pressure becomes greater from above. These relief-valves have acted very satisfactorily. The lock-gates are mostly of wrought iron, made on the arch principle, and partly buoyant. In their design some special features have been adopted, which may be seen in the working drawings laid before the Section for inspection by any Members feeling interest in the subject. The gates work remarkably well and keep practically water-tight, a somewhat unusual success in double skin lock-gates. Other drawings and details of the dock-works are also open for inspection.

Improvements are also being carried on by the Corporation in the removal of some of the projecting points of rock, and the deepening of the bed of the river. The general line of slope to which it is proposed ultimately to reduce the bed is shown on the longitudinal section of the river (Plate VII.).

Another important work being carried out inside of the harbour is the formation of a new quay, about half a mile long, the construction of the retaining-wall of which may be a matter of some interest. It is being built in a trench, without a coffer-dam, partly within and partly along the edge of the water of the harbour. With the exception of the face, which is of dressed stone, and the coping, which is of granite, the whole of the wall is of concrete, laid in steps and beds alternately of blue lias lime and of Portland cement concrete, the object being to gain the advantage of the comparative cheapness of the lime, and the more quick and certain setting of the cement.

A drawing of this work is shown with the others. The two separate portions of the work are found to bond well together, and the system is one which admits of rapidity of construction, and without much skilled labour.

In addition to the dock which has been alluded to as under construction on the Gloucestershire side of the Avon, there is also another dock on the Somersetshire side at Portishead. As details of each of these docks have already been laid before the Section, it is not necessary again to give the particulars which the author had prepared respecting them.

Report of the Committee, consisting of the Rev. H. F. Barnes, H. E. Dresser (Secretary), T. Harland, J. E. Harting, Professor Newton, *and the* Rev. Canon Tristram, *appointed for the purpose of inquiring into the possibility of establishing a "Close Time" for the protection of indigenous animals, and for watching Bills introduced into Parliament affecting this subject.*

Your Committee have again to express their regret that, notwithstanding every exertion on their part, they were unable to obtain the introduction into Parliament, in time to allow of its being successfully carried, of the Bill which their former Reports have indicated to be most desirable; but at the same time they have great pleasure in stating that Mr. Henry Chaplin, M.P. for Mid Lincolnshire, holds out to them the hope that he will at an early period of the next session bring forward such a measure.

Your Committee continue to receive assurances of the efficient working of the Sea-birds Preservation Act of 1869.

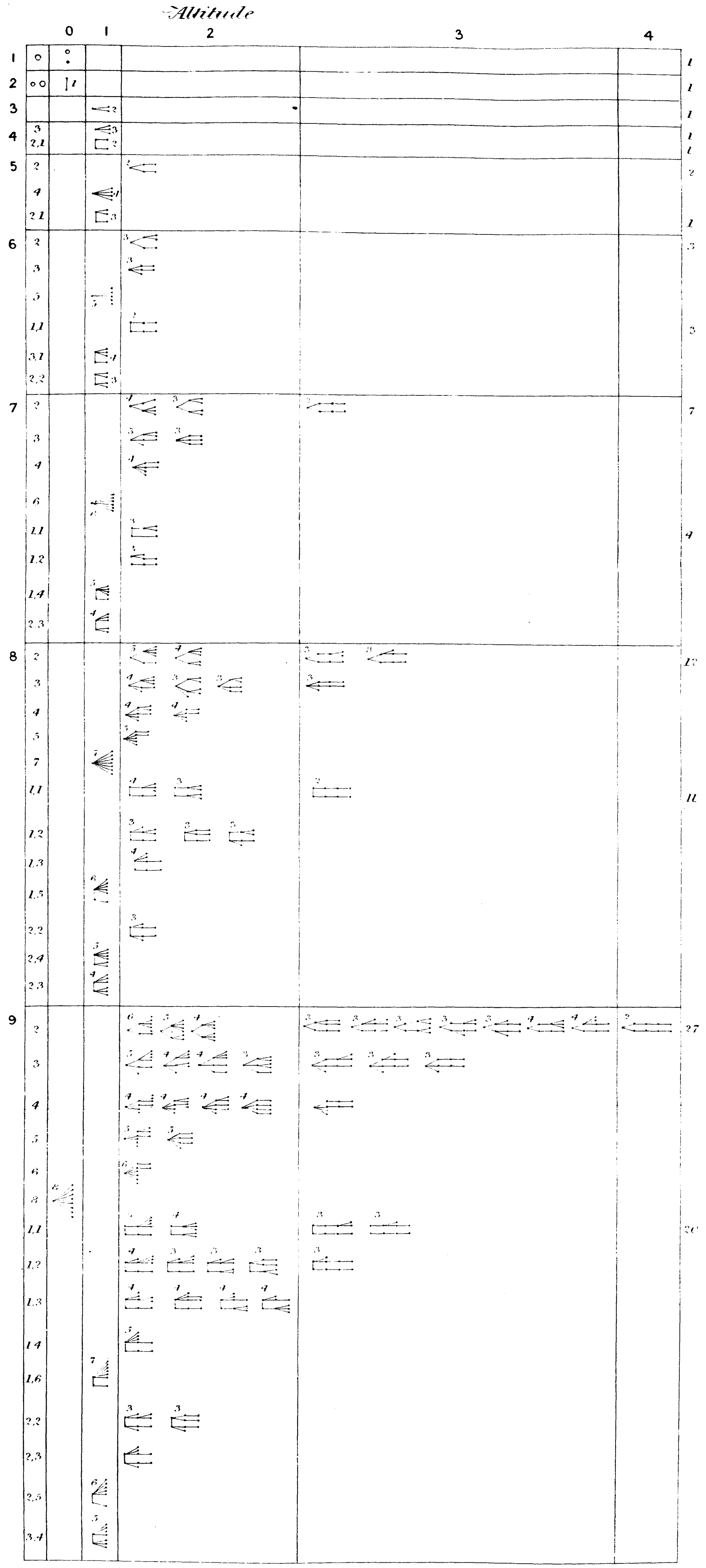
In view of the proceedings likely to be taken in the ensuing session, as above stated, your Committee respectfully solicit their reappointment.

Report of the Committee appointed to Superintend the Publication of the Monthly Reports of the progress of Chemistry, the Committee consisting of Professor A. W. Williamson, *F.R.S.*, Professor Frankland, *F.R.S., and* Professor Roscoe, *F.R.S.*

The Committee have much pleasure in reporting that the Chemical Society has continued to publish the monthly reports of the progress of Chemistry, which were commenced five years ago by the aid of a grant of money from the Association, and also raised by donations from members of the Society.

These reports have been edited by Mr. Watts, to whose earnest and assiduous labours much of the success of the reports must be attributed. A considerable number of chemists divide among themselves the labour of preparing abstracts of the chemical papers which have been published in the course of each month.

In spite of the smallness of the remuneration offered to these gentlemen, the expense of publishing the abstracts is very considerable, and has


Altitude

become a serious strain upon the resources of the Society, more especially now that the aids from the Association and from private sources have already been continued for the period which had been assigned to them.

The Committee have reason to believe that these abstracts supply an important need for the advancement of our science, and that they are highly valued by the members of the Society and other chemists.

They confidently trust that the Society may be able to carry on the important work which has been thus auspiciously commenced; and they congratulate the Association on the service which it has rendered to science by supplying to that enterprise the aid which was absolutely needed in its infancy.

Report on Dredging off the Coast of Durham and North Yorkshire in 1874. By GEORGE STEWARDSON BRADY, *C.M.Z.S., and* DAVID ROBERTSON, *F.G.S.*

A BRIEF account of the dredging undertaken by us on the coast was presented to the British Association last year, but no attempt was then made to give lists or detailed observations. The following Report embraces lists of all that came under our notice in the groups of Mollusca, Entomostraca (Ostracoda and Copepoda), Polyzoa, Hydrozoa, Spongozoa, and Foraminifera. Amongst Echinodermata our captures did not include any species requiring special notice, whilst among the larger Crustacea (Decapoda) the only species of unusual occurrence in the district were *Stenorhynchus longirostris*, Fabr., *Portunus depurator*, Linn., and *Ebalia tumefacta*, Mont. Several species belonging to an interesting group of minute Crustaceans not hitherto noticed in the British seas (Isopoda Remigantia of G. O. Sars) were taken, but we are not yet able to name more than one or two of them with certainty. Special attention was given to the Acarides, a large number of which were obtained, and amongst them some previously undescribed species which have been figured and described by one of us in the 'Proceedings of the Zoological Society' for the present year. But the greatest number of novelties occurred amongst the Copepoda, 28 species of this group being new to science, and 11 new to British records.

The Mollusca, Ostracoda, and Foraminifera of the Northumberland and Durham coasts had been so fully investigated by the Dredging-Expeditions of the Tyneside Naturalists' Field-Club, undertaken with the help of the British Association in the years 1862, 1863, 1864, that little was left to be done in those branches. But, as might be expected, notwithstanding that much of the ground had already been well searched, we are now able to add to the number of species noted in the previous Reports, while, on the other hand, some species contained in the earlier lists are absent from ours*.

To the list of Testaceous Mollusca prepared by the late Mr. Alder from the

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* It must be noticed, however, that the area embraced in our dredgings of last year (1874), though of nearly similar extent, is not quite identical with that investigated by the Tyneside Field-Club in the years 1862–64. The present Report refers to the coast of Durham and the northern part of Yorkshire as far as Scarborough, while those of the earlier expeditions embraced the seaboard of the two counties of Durham and Northumberland, thus reaching nearly sixty miles further north, while, on the other hand, our last year's explorations went about thirty-five miles further south than those of ten years ago.

OSTRACODA.

*** indicates prevailing, ** moderately common, * rare species, these indications referring only to the localities under which they appear. Those marked with the prefixed asterisk are new to the district.

Genera and Species.	7 miles off Marsden; muddy sand. 33 fa.	30 miles off Sunderland; sand and gravel. 40–45 fa.	14 miles off Seaham; muddy sand. 35 fa.	4 miles off Hawthorn; gravelly. 20 fa.	5 miles off Castle Eden; coarse gravel. 20 fa.	5 miles off Hartlepool, muddy sand. 20 fa.	8 miles off Staiths; shells and gravel. 25 fa.	5 miles off Red Cliff; gravel and dead shells. 30 fa.	5 miles off Robin Hood's Bay; zoophytes and gravel. 30 fa.	3 miles off Scarborough, sandy. 17 fa.	5 miles off Scarborough; gravel and broken shells. 25 fa.
Pontocypris mytiloides (*Norm.*)				**	**	*	**	**	**	*	**
*—— trigonella, *Sars*								*	*		
*Bairdia inflata (*Norm.*)								*			
Cythere lutea, *Müll.*				*							
*—— viridis, *Müll.*										**	
—— pellucida, *Baird*			*	*			*		*	**	*
—— semipunctata, *Brady*				*				*			
—— castanea, *Sars*										*	*
*—— albomaculata, *Baird*									**	*	
—— tenera, *Brady*	**	**	**	**	***	**	**	**	**	**	**
*—— convexa, *Baird*									*		
—— limicola (*Norm.*)	**	**	**			*					
*—— finmarchica (*Sars*)				**	**				**		*
—— Robertsoni, *Brady*			*	**	**		*			**	*
*—— villosa (*Sars*)								**		**	
—— quadridentata, *Baird*	**	*	*	*		**	*				
—— tuberculata (*Sars*)	**	*	**	*	*	***	*	*	*	*	**
—— emaciata, *Brady*								*	*	*	*
—— Dunelmensis (*Norm.*)	**		**			*				*	
—— Jonesii (*Baird*)	***	*	**	*		**					
*—— angulata (*Sars*)										*	
—— concinna, *Jones*	*		**			*				*	
Cytheridea papillosa, *Bosq.*	***	**	***	**		***	*	*	**	**	
*—— elongata, *Brady*									*	**	

Eucythere declivis (*Norm.*)	**	*		*		*	**			*	
—— Argus (*Sars*)	**	**	*	**	*	**		*	**	**	*
—— anglica, *Brady*	*	*	*								
Krithe Bartonensis (*Jones*)	*		**							*	
Loxoconcha guttata (*Norm.*)	**	**	**	*		**	*	*			*
—— granulata, *Sars*			*	*							
—— tamarindus (*Jones*)		**		**	***	*	**	***	**	**	***
—— multifora (*Norm.*)		*	*				*	*		*	**
Xestoleberis depressa, *Sars*				**	***		**	***	***	*	***
Cytherura angulata, *Brady*				**	*			**	**		
—— striata, *Sars*		*			**	*	*	*	***	**	**
—— similis, *Sars*									*		
—— producta, *Brady*				*	**		*	***	*	*	*
—— acuticostata, *Sars*				**	**		*		**	*	**
—— clathrata, *Sars*				*				*	*	*	
—— cellulosa (*Norm.*)									*	*	*
*—— fulva, *Brady and Robertson*				*							
*—— flavescens, *Brady*										**	*
Cytheropteron nodosum. *Brady*		*			*					*	
—— latissimum (*Norm.*)	**	***	**	**	**	**	**	**	**	**	***
*—— alatum, *Sars*		*									
*—— subcircinatum, *Sars*									*		
Bythocythere simplex (*Norm.*)	**	*	**	*		**			*	*	
—— constricta, *Sars*					*		*	**	**	**	**
—— turgida, *Sars*	*	**	*	**		*					*
*Pseudocythere caudata, *Sars*								**			
Cytherideis subulata, *Brady*										*	*
*—— Hilda, n. sp.									*	*	
Sclerochilus contortus (*Norm.*)	*	**	**	**	**		**	***	**	**	**
Xiphichilus tenuissima (*Norm.*)			*								
Paradoxostoma variabile (*Baird*)		*		*			**	**	**	*	**
*—— abbreviatum, *Sars*				*				*		*	
—— ensiforme, *Brady*					**		*		*	**	*
—— flexuosum, *Brady*		*		**	*			**	**	*	*
*—— Fischeri, *Sars*	*		**								
*—— arcuatum, *Brady*				*					*		
*—— Normani, *Brady*				**	*				**		
*Philomedes interpuncta (*Baird*)	*	*		*					*		
*Asterope Mariæ (*Baird*)							*				*
*—— teres, *Norm.*			*								
Bradycinetus Brenda (*Baird*)			**							*	
*Polycope orbicularis, *Sars*			*	*				**			
*Cytherella scotica, *Brady*			*								

FORAMINIFERA.

Note.—The species marked (*) do not appear in the "Dredging Reports" of 1862, 1863, 1864, nor in Mr. H. B. Brady's 'Catalogue of the Recent Foraminifera of Northumberland and Durham,' published in 1865. For the most part they are new to the district, but some few had been found in the interim, though their occurrence had not been recorded; and in two or three cases forms to which specific names are now given by general consent were not distinguished from their respective types in former lists. Two of the species so marked, *Lagena trigono-marginata*, P. & J., and *Webbina hemisphærica*, P., J. & B., are new to Britain.

*** indicates prevailing forms, ** indicates moderately common, * indicates rare, and refer only to the haul they were taken in.

Genera, Species, and Varieties.	7 miles off Marsden; muddy sand. 33 fa.	20 miles off Sunderland; muddy sand. 45 fa.	30 miles off Sunderland, gravelly. 40 fa.	12 miles off Seaham; muddy sand. 35 fa.	4 miles off Hawthorn; shelly gravel. 20 fa.	6 miles off Hawthorn; gravelly sand. 20 fa.	5 miles off Castle Eden; coarse gravel. 20 fa.	5 miles off Hartlepool; muddy sand. 20 fa.	8 miles off Staiths; broken shells and gravel 25 fa.	5 miles off Red Cliff; large gravel and broken shells 25–30 fa.	4 miles off Robin Hood's Bay; broken shells and zoophytes 30 fa.	5 miles off Robin Hood's Bay; stones and *Filograna implexa*. 25 fa	Off Scarborough; sandy bottom. 17 fa.	Off Scarborough; broken shells and gravel. 25 fa.
Suborder IMPERFORATA.														
Family Miliolida.														
Cornuspira foliacea, *Phil.*	..	..	..	*	*	..	..	..	..	*	..	..	*	
Biloculina ringens, *Lamk.*	**	***	***	**	**	**	**	*	.	**	*	*	**	
—— depressa, *D'Orb.*	**	***	***	**	**	**	**	*	**	***	**	**	..	**
—— elongata, *D'Orb.*	**	**	***	*	*	**	*			**	.	*		
Triloculina trigonula, *Lamk.*	*	*	***	..	***	***	***	**	*	**	**	**	..	*
—— oblonga, *Mont.*	..	..	..	..	**	**	*	..	**	**	..	*	*	
*—— tricarinata, *D'Orb.*	..	..	..	..	..	..	..	..	..	..	..	*		

*—— Brongniartii, *D'Orb.*										*		**		
Quinqueloculina seminulum, *Linn.*	***	***	***	**	**	***	**	***	**	***	***	**	***	**
—— bicornis, *W. & J.*			*		**	***	**	*	**	***	***	**	*	
—— secans, *D'Orb.*		**	*						*		**	**	**	*
—— Ferussacii, *D'Orb.*	*	*	*				*			*	*	*		*
*—— pulchella, *D'Orb.*			*			*	*				*			
—— subrotunda, *Mont.*		*	*	*	**	**	*	*	**	**	**	**	***	***
Spiroloculina limbata, *D'Orb.*			**		**	***	***	**	**	**	***	**	*	
—— planulata, *Lamk.*			*		**	**	**			*		*		
*—— canaliculata, *D'Orb.*												*		
—— excavata, *D'Orb.*				*			**			**		**		
Family Lituolida.														
*Trochammina incerta, *D'Orb.*								*						
*Webbina hemisphærica, *J, P. & B.*	*									*				
*Lituola nautiloidea, *Lamk.*	**	*		**				*						
—— scorpiurus, *Montf.*	***	**		***				**		*	*	**		
—— Canariensis, *D'Orb.*				*	***	***	***	*	**	***	*	***	**	**
Suborder PERFORATA.														
Family Lagenida.														
Lagena sulcata, *W. & J.*	***	*	*	***	**		**	**	**	*	**	*	***	***
—— —— *var.* interrupta				*				**	*					*
*—— Lyellii, *Seguenza*	*									**				
—— lævis, *Mont.*	**		*	*	*							**	**	
*—— gracillima, *Seguenza*	**	**	***	**		*	*							
—— striata, *Mont.*	***	***	*	***	*		*	**		*	*	**	*	
—— semistriata, *Will.*		**		**	*	**	*	*	**	*	*		*	
—— distoma, *P. & J.*	*			**										
—— globosa, *Mont.*	**	**	**	**	*	*		*	**	**			*	
—— marginata, *W. & J.*	***	*		**	**	***	**	**	***	**	***	***	**	**
*—— ornata, *Will.*										*				

FORAMINIFERA (*continued*).

Genera, Species, and Varieties.	7 miles off Marsden, muddy sand. 33 fa.	20 miles off Sunderland, muddy sand. 45 fa.	30 miles off Sunderland, gravelly. 40 fa.	12 miles off Seaham; muddy sand. 35 fa.	4 miles off Hawthorn; shelly gravel. 20 fa.	6 miles off Hawthorn, gravelly sand. 20 fa.	5 miles off Castle Eden; coarse gravel 20 fa.	5 miles off Hartlepool, muddy sand. 20 fa.	8 miles off Staiths, broken shells and gravel. 25 fa.	5 miles off Red Cliff, large gravel and broken shells. 25–30 fa.	4 miles off Robin Hood's Bay; broken shells and zoophytes. 30 fa.	5 miles off Robin Hood's Bay; stones and *Filograna implexa*. 25 fa.	Off Scarborough; sandy bottom. 17 fa.	Off Scarborough; broken shells and gravel. 25 fa.
*Lagena trigono-marginata, *P. & J.*†								*				*		
—— squamosa, *Mont.*	*	**	*	**	*	*		*	*	*	*	*	*	
—— —— *var.* hexagona	**			*		*	*	*					*	
—— melo, *D'Orb*	*			*	*							*		
—— caudata, *D'Orb.*										*				
Nodosaria scalaris, *Batsch.*	**			*										
—— pyrula, *D'Orb.*	*	*		**										
Dentalina communis, *D'Orb.*			*	*		*				*		*		*
*—— pauperata, *D'Orb*	**	**	**	**	*	*		*			*			*
*—— consobrina, *D'Orb.*	**	*		**										
*—— obliquestriata, *Reuss*			*											
Vaginulina linearis, *Mont*										**	*	**		
—— legumen, *Linn*										*				
*Marginulina raphanus, *Linn.*						*					*	*		
Cristellaria rotulata, *Lamk.*	*			*						*		**	*	
—— crepidula, *F. & M*										*				
Polymorphina lactea, *W. & J*	**	**	***	**		**	***	*	**	**	*	**		*
*—— gibba, *D'Orb.*		**	**	**		*	**	**	*	**	**	**		**
*—— fusiformis, *Roemer*												*		
—— compressa, *D'Orb.*						*		***	*				*	
*—— communis, *D'Orb.*					*								*	
*—— oblonga, *Will.*					*	*						*		

*—— concava, *Will.*										*				
—— Orbigniana, *Zbor.*	**	**	**							*	*			
Family Globigerinida.														
Orbulina universa, *D'Orb.*		*	*										*	
Globigerina bulloides, *D'Orb.*											*			
Textularia sagittula, *Defrance*	*		***		**	**	**	**	**	**	**	**	***	***
—— trochus, *D'Orb.*			*									*		
—— pygmæa, *D'Orb.*				*				*						
Verneulina polystropha, *Reuss.*	*			**	*	*		***	*			**	*	
Bulimina marginata, *D'Orb*	***	**	*	***	**	*		**	**	*		*	*	
—— pupoides, *D'Orb.*	*			*	*				*		*	*	*	
—— ovata, *D'Orb.*	**			*										
Discorbina globularis, *D'Orb.*	*		**	*	**	**	**	**	**	**	**	**	**	**
*—— ochracea, *Will.*				*								*		
Planorbulina mediterranensis, *D'Orb.*			**		**	*	**	**	**	**	*	**	**	***
Truncatulina lobatula, *Walker*	***	**	**	**	**	**	***	*	**	***	***	**	**	***
—— refulgens, *Montf.*										*				
Rotalia Beccarii, *Linn.*	**	**	**	**		*	*	***		**	*	**	**	***
—— nitida, *Will.*	*			*	*	*						*		
*Tinoporus lucidus, *Brady*													*	
*Operculina ammonoides, *Gron.*	*													
Family Nummulinida.														
Polystomella crispa, *Linn.*								*						*
—— striato-punctata, *F. & M.*	*	*			**	**	*	**	**	**	*	*	**	**
Nonionina depressula, *J & W.*	**	*		*	*	**		**	**	*	*	**	**	**
—— umbilicatula, *Mont.*				*										
—— turgida, *Will.*				**									*	

We are greatly indebted to Mr. H. B. Brady for his valuable assistance with doubtful species of Foraminifera, and to the Rev. A. M. Norman for equally valuable help with the Mollusca.

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† With respect to this species we have the following note from Mr. H. B Brady:—"*Lagena trigono-marginata*, of Parker and Jones (Phil. Trans. 1865, vol. clv. p. 419, pl. 18. fig. 1, *a*, *b*) is a form previously described by Seguenza (Foram. Monotal. Messina, 1862, pt ii p. 75, pl. 2. figs 60–62) as *Trigonulina globosa*. The subdivision of the genus *Lagena* adopted by Prof. Seguenza has not been followed, so far as we know, by any other writer, and, indeed, is quite needless. Referring this variety, therefore, to *Lagena*, it becomes necessary to accept Messrs. Parker and Jones's specific name, the term '*globosa*' as connected with that genus being already in use."

three years' dredgings of the Tyneside Naturalists' Field-Club, we are now able to add 21 species.

From the same dredgings 19 species of Ostracoda were catalogued by Mr. Norman, but five years later the number was increased to 47 by Mr. G. S. Brady. Our present list includes 71 species, one of which, *Cytherideis Hilda*, is new to science.

The Rev. A. M. Norman, who accompanied us during part of the dredging-expedition, has kindly examined and reported on the Polyzoa, Hydrozoa, and Spongozoa. Among the Polyzoa is one interesting form new to the British seas, *Bugula fruticosa*, Packard; one Hydrozoon new to the east coast, *Lafoëa pocillum*, Hincks; and two undescribed sponges, *Hymeniacidon virgulatus* and *Halichondria virgea*, both of which are here described by Dr. Bowerbank.

The Foraminifera from the earlier dredgings were ably worked out by Mr. H. B. Brady, and numbered 70 species, a total subsequently increased to 74, or perhaps rather more. The list will now, with the additions we have made, comprise 94 species, or rather more than 60 per cent. of the recorded British Foraminifera.

But apart from the number of species obtained there is much of interest in their distribution, as may conveniently be seen in the annexed Tables. It was shown by Mr. Alder* that the Testaceous Mollusca of the Northumberland coast present a distinctly boreal character, which is shared more or less by the whole invertebrate fauna; but it may be remarked with regard to the Ostracoda that this character is by no means so apparent. It will be seen from the Table that *Cythere lutea*, *C. viridis*, *C. angulata*, *Cytheridea punctillata*, and *Cytherura nigrescens* are absent or rare. All these species are characteristically boreal, and strongly represented in the Posttertiary ("Glacial") clays of Scotland. At the same time it is interesting to note that although *Cythere lutea* and *Cytherura nigrescens* are absent or rare in the dredgings from this coast, they are extremely common between tide-marks, where they must be subject to much greater variation of temperature. But if a low temperature were specially congenial to these species, we should expect to find them further out at sea, where they certainly lived in great abundance during the deposition of our Posttertiary clays. It is a curious fact that these two species are confined almost entirely to the littoral and Laminarian zones of the east coast, but are abundant in deep water on the west, as, for instance, in the Frith of Clyde. On the whole, then, we must conclude that the Ostracoda and Foraminifera of the north-east coast of England do not present that marked arctic character which has been noticed in a considerable group of the Northumbrian Mollusca; but that there is, on the contrary, a marked absence of some typically northern forms which are abundant in the warmer seas of the western coast. Nor can we suppose that a cold arctic current is the only or even perhaps the chief agent in the continued existence of this peculiar Northumbrian molluscan fauna, else we could scarcely fail to have had an equally well-marked development of arctic types amongst other groups of invertebrata whose organization renders them even more easy of distribution. We must therefore, in the absence of more accurate information, look to some strictly local circumstances as having been the chief causes of the retention of the species in question over particular circumscribed areas.

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* Natural-History Transactions of Northumberland and Durham, 1865.

TESTACEOUS MOLLUSCA.

The letters c, mc, r, mr, signifying common, moderately common, rare, moderately rare, refer only to the hauls in which the species were taken. Those marked * are new to the district.

Brachiopoda.

Argiope capsula, Jeff. 4 miles off Robin Hood's Bay, 30–35 fathoms; bottom broken shells and zoophytes.

Conchifera.

Anomia ephippium, Linn.: mr. Small in most of the gatherings where the ground was hard.

—— ——, var. *aculeata*, Mull.: mr. Small in most gatherings on hard ground.

Pecten pusio, Linn.: mc. 4–6 miles off Hawthorn and Redcliff, 20–30 fa.; gravel and dead shells.

—— *opercularis*, Linn.: mr. The living all small in various gatherings.

—— *tigrinus*, Mull.: mc. Off Hawthorn, Staiths, Redcliff, and Robin Hood's Bay, 20–37 fa.; gravelly.

—— *similis*, Laskey: mr. 5 miles off Redcliff, 30 fa.; gravel and dead shells.

—— *striatus*, Mull.: mr. Off Castle Eden and Redcliff, 20–30 fa.; gravelly.

*—— *varius*, Linn. Dead, off Robin Hood's Bay, 30 fa.; gravel, dead shells, and zoophytes.

Mytilus edulis, Linn.: r. Dead shell, off Redcliff, 30 fa.; gravel and dead shells.

—— *modiolus*, Linn.: mc. Small, none above an inch, 6 miles off Hawthorn, 37 fa.; sandy gravel.

Lima Loscombii, G. B. Sow.: mr. Hawthorn and Redcliff, 20–37 fa.; sandy gravel and dead shells.

—— *subauriculata*, Mont.: mr. 5 miles off Redcliff, 30 fa.; sandy gravel and dead shells.

Modiolaria discors, Linn.: mr. 6 miles off Hawthorn, 20 fa.; sandy gravel.

—— *nigra*, Gray: r. Dead valves, off Staiths, 25 fa.; gravelly.

—— *marmorata*, Forbes. In the *Ascidia mentula*, off Seaham, 35 fa.; gravelly sandy mud.

Crenella decussata, Mont.: c. 14 miles off Seaham, 35 fa.; sandy mud.

Arca tetragona, Poli: r. Small, 5 miles off Castle Eden, 20 fa.; coarse gravel.

Nuculus nucleus, Linn.: Hawthorn and Redcliff, 20–30 fa.; sandy gravel and dead shells.

—— *tenuis*, Mont.: c. Fry 20 miles off Sunderland, 45 fa.; muddy sand.

—— *nitida*, Sow. Dead shell, with the last.

Leda (caudata) minuta, Mull.: mc. In most of the gatherings.

**Pectunculus glycymeris*, Linn. A dead shell, 5 miles off Redcliff, 30 fa.; gravel and dead shells.

Cardium echinatum, Linn. Dead valves, 5 miles off Robin Hood's Bay, 30 fa.; gravelly.

—— *exiguum*, Gmel.: r. With the above.

—— *edule*, Linn.: r. Dead valves, off Durham coast.

—— *fasciatum*, Mont. Off Hawthorn and Castle Eden, 20–27 fa.; sandy gravel.

—— *norvegicum*, Spengl.: mr. Dead valves, 6 miles off Hawthorn, 20 fa.; sandy gravel.

Lucina borealis, Linn.: r. 8 miles off Staiths, 25 fa.; sandy gravel and dead shells.

Axinus flexuosus, Mont.: r. 5 miles off Hartlepool, 35 fa.; muddy sand.

**Diplodonta rotunda*, Mont. 6 miles off Hawthorn, 37 fa.; sandy gravel.

Kellia suborbicularis, Mont.: mr. Off Hawthorn and Redcliff, 20–30 fa.; sandy gravel.

Montacuta substriata, Mont.: mc. Off Redcliff and Robin Hood's Bay, 30 fa.; gravel and dead shells.

Cyprina islandica, Linn.: mr. Small, off Marsden and Redcliff, 30–33 fa.; gravel and muddy sand.

Astarte sulcata, Da Costa: c. 5 miles off Hartlepool, 35 fa.; muddy sand.

—— *compressa*, Mont.: mc. With the above.

—— *triangularis*, Mont.: mr. With the above.

Venus exoleta, Linn. Dead valves, 6 miles off Hawthorn, 20 fa.; sandy gravel.
—— *lincta*, Pult.: mr. Off Marsden, 33 fa.; muddy sand.
—— *fasciata*, Da Costa: mc. Off Redcliff and Robin Hood's Bay, 30 fa.; gravelly.
—— *casina*, Linn.: mc, and large. 14 miles off Seaham, 35 fa.; sandy mud.
—— *ovata*, Penn.: mc. Large, off Hartlepool and Redcliff, 30 fa.; muddy sand and gravel.
—— *gallina*, Linn.: mc. Off Redcliff, 30 fa.; gravelly.
Tapes virgineus, Linn.: mc. Off Hawthorn and Castle Eden, 20 fa.; sand and gravel.
Lucinopsis undata, Penn.: r. Off Hartlepool, 36 fa.; muddy sand.
Tellina crassa, Gmel. Off Hawthorn, dead shells, 20 fa., sandy gravel.
*—— *tenuis*, Da Costa: mr. Off Redcliff, 30 fa.; gravel and dead shells
—— *pusilla*, Phil.: mr. With the above.
*—— *fabula*, Gron.: mc. Large, off Seaham, 35 fa.; sandy mud
Psammobia tellinella, Lamk.: mr. 14 miles off Seaham, Hawthorn, 35 fa.; sandy mud and gravel.
—— *ferroensis*, Chem.: mc. Off Hawthorn, 20 fa., sandy gravel.
Mactra subtruncata, Da Costa: r. Castle Eden, 20 fa., gravelly.
—— *elliptica*, Brown. Off Hawthorn and Redcliff.
*—— *stultorum*, Linn. A valve, off Scarborough, 17 fa.; sandy.
Scrobicularia prismatica, Mont.: mc. Off Seaham, 35 fa., sandy mud.
—— *alba*, Wood: r. With the above.
Solen pellucidus, Penn. 20 miles off Sunderland, 45 fa.; muddy sand.
*—— *ensis*, Linn. A broken valve, off Redcliff, 30 fa., gravelly.
Thracia papyracea, Poli: mr. Off Hawthorn, 20 fa., sandy gravel.
—— ——, var. *villosiuscula*, Macq.: r. With the above.
Neæra cuspidata, Olivi. One young, covered with sand, off Seaham, 35 fa.; sandy mud.
Corbula gibba, Olivi: mc. Off Sunderland and Seaham, 35–45 fa.; muddy sand.
Mya truncata, Linn. Valves, and some fry between Castle Eden and Redcliff, 20–35 fa.; gravelly.
Saxicava rugosa, Linn.: mc. None large, in most of the gatherings.
—— *arctica*, Linn.: r. Redcliff, 30 fa.; gravel and dead shells.
**Pholas crispata*, Linné. Fragment of large shell, between Castle Eden and Redcliff, 20–35 fa.; gravelly.

Solenoconchia.

Dentalium entalis, Linn.: c, and large. Off Hawthorn, 20 fa.; sandy gravel and other gatherings.
*—— *tarentinum*, Lamk.: r. Small, dead, off Hartlepool, 35 fa.; muddy sand.

Gasteropoda.

Chiton cinereus, Linn.: r. Off Staiths, 25 fa.; gravel and dead shells.
—— *marmoreus*, Fabr.: r. Robin Hood's Bay, 30 fa.; gravel and zoophytes.
Tectura virginea, Mull.: r. Off Castle Eden, 20 fa.; coarse gravel.
Emarginula fissura, Linn.: mr. Off Redcliff, 30 fa.; gravel and dead shells.
Capulus hungaricus, Linn.: mr. Small, off Seaham and Robin Hood's Bay, 35 fa.; sandy mud and gravel.
**Trochus magnus*, Linn.: r. Dead, off Hawthorn, 20 fa.; sandy gravel.
—— *tumidus*, Mont.: mc. Off Redcliff, 30 fa., gravelly and dead shells, mostly small.
—— *cinerarius*, Linn.: r. Off Castle Eden, 20 fa.; coarse gravel.
—— *Montacuti*, Wood: r. Off Redcliff, 30 fa.; gravel and dead shells.
—— *millegranus*, Phil.: c. Off Castle Eden and Redcliff, 20–30 fa.; gravel and dead shells.
—— *zizyphinus*, Linn.: c. Off Castle Eden and Redcliff, 20–30 fa.; gravel and dead shells.
*—— ——, var. *Lyonsii*, Leach. With the above.
**Lacuna crassior*, Mont.: r. Off Castle Eden, 20 fa.; coarse gravel.
—— *pallidula*, Da Costa: r. Off Staiths, 25 fa.; gravel and dead shells.
Rissoa punctura, Mont.: mc. Off Marsden and Seaham and Hawthorn, 20–35 fa.; sandy gravel.

Rissoa parva, Da Costa: mc. Durham and Northumberland coasts, 20–30 fa.
—— ——, var. *interrupta*. More common.
—— *striata*, Adams: mc. In most of the gatherings.
—— *vitrea*, Mont.: r. Off Hawthorn, 35 fa.; sandy gravel.
*—— *soluta*, Phil.: mc. Obtained with the above
Cæcum glabrum, Mont.: mc. Off Seaham and Redcliff, 30–35 fa.; sandy mud and gravel.
Turritella terebra, Linn. Off Marsden and Seaham, 35 fa.: muddy sand.
Scalaria Trevelyana, Leach: mc Off Redcliff and Robin Hood's Bay, 30–35 fa.; gravelly
Acis ascaris, Turton: r. Off Scarborough, 17 fa.; sandy.
**Odostomia rissoides*, Hanley: r. Off Hawthorn, 20 fa, sandy gravel.
*—— *acuta*, Jeff: mr. Off Hartlepool and Scarborough, 25–35 fa.; muddy sand and gravel.
—— *unidentata*, Mont.: r. Off Hawthorn, 20 fa, sandy gravel.
—— *obliqua*, Alder. r. Off Marsden, 35 fa, muddy sand.
*—— ——, var. *Warreni*, Thompson Off Hawthorn.
—— *indistincta*, Mont mc Off Robin Hood's Bay, 30 fa.; gravelly.
—— *interstincta*, Mont.: r. Off Castle Eden, 20 fa, gravelly.
—— *spiralis*, Mont mc. Robin Hood's Bay, 30 fa.; gravelly.
—— *lactea*, Linn: mc. Redcliff, 30 fa., gravel and dead shells.
*—— *acicula*, Phil mc. Off Hawthorn and Scarborough, 20–25 fa.: sandy gravel.
Stilifer Turtoni, Brod: mr. Off Sunderland and Seaham, 20–35 fa.; on spines of *Echinus pictus*.
Eulima distorta, Desh.: c. Off Hawthorn, 20 fa.; sandy gravel.
—— ——, var *gracilis* With the above
—— *bilineata*, Alder mc. Off Seaham and Hartlepool, 35 fa.; muddy sand.
Natica islandica, Gmel r. Off Redcliff, 30 fa.; gravel and dead shells.
—— *grœnlandica*, Beck: r. 20 miles of Sunderland, 45 fa., muddy sand.
—— *Alderi*, Forbes: mc. Small, in most of the gatherings.
—— *Montacuti* (*Montagui*), Forbes: mr In a few of the gatherings.
Velutina lævigata, Penn: mr. Off Robin Hood's Bay, 30 fa; gravel and zoophytes.
Aporrhais pes-pelecani, Linn: mc. Off Marsden and Sunderland, 33–45 fa.; muddy sand.
Buccinum undatum, Linn. Obtained with the above, the shells thin and small with high ridges
Trophon truncatus, Strom: mc. Redcliff and Robin Hood's Bay, 30–35 fa.; gravelly.
Fusus gracilis, Da Costa: mc 7 miles off Marsden, 30 fa.; muddy sand.
—— *antiquus*, Linn: mc. With the above, mostly small, some large.
—— *propinquus*, Alder: mr. Off Marsden, 33 fa.: muddy sand.
Nassa incrassata, Strom: mc. Hawthorn and Redcliff, 20–30 fa.; sand and gravel.
Defrancia linearis, Mont.: mc. Redcliff, 30 fa.; gravel and dead shells.
*—— *purpurea*, Mont. Obtained with the above.
Pleurotoma brachystoma, Phil mr Off Marsden, 33 fa.; muddy sand.
—— *turricula*, Mont.: mc. Off Redcliff, 30 fa.; gravel and dead shells.
—— *Trevelyana*, Turton: mc. Off Robin Hood's Bay, 30 fa.; gravel and zoophytes.
Cypræa europæa, Mont: r. Dead shell in several gatherings.
Cylichna umbilicata, Mont.: mc. Castle Eden and Redcliff, 20–30 fa.; gravelly.
—— *cylindracea*, Penn.: c. With the above.
**Utriculus mammillatus*, Phil.: mr. With the above.
—— *truncatulus*, Brug.: mc. Off Sunderland and Redcliff, 30–45 fa.; muddy sand and gravel.
—— *obtusus*, Mont.: r. Off Sunderland, 45 fa.; muddy sand.
**Actæon tornatilis*, Linn.: mc. All small, none more than ¼ inch, off Hawthorn 20 fa.; sandy gravel.
Philine scabra, Mull.: mr. Off Marsden, 33 fa.; muddy sand.

PTEROPODA.

**Spirialis retroversus*, Flem.: r. 5 miles off Redcliff, 30 fa.; gravel and dead shells.

Subclass ENTOMOSTRACA.

Order COPEPODA.

Calanus finmarchicus (Gunner). Occurs in almost every dredging.

*—— _longiremis_ (Claus). One specimen found in a depth of 35 fa., off Robin Hood's Bay.

Dias longiremis, Lilljeborg. Abundant in many dredgings, and occurred more or less in all.

Temora longicornis (Muller). Occurred in most of the dredgings.

Isias clavipes, Boeck. In a depth of 35 fa., off Robin Hood's Bay.

Centropages hamatus (Lilljeborg). Found in many of the dredgings.

Cyclops littoralis, Brady. In a depth of 45 fa., 20 miles east of Sunderland.

Thorellia brunnea, Boeck. Off Robin Hood's Bay and Staiths, 25–35 fa.

Cyclopsyllus elongatus, nov. gen. et sp. In a depth of 27 fa., off Hawthorn; sandy bottom.

*_Misophria pallida_, Boeck. In company with the preceding species.

Lophophorus insignis, nov. gen. et sp. One specimen taken in the same dredging as the preceding.

Longipedia coronata, Claus. Abundant in almost every dredging.

Ectinosoma curticornis, Boeck. Almost always in company with the preceding, and equally abundant; both species prefer sandy ground.

*—— _Sarsii_, Boeck. Off Robin Hood's Bay, 35 fa.

—— _erythrops_, nov. sp. In depths of 20–35 fa., off Hartlepool, Red Cliff, Staiths, and Robin Hood's Bay; but always scarce.

—— _tenuis_, nov. sp. Off Hawthorn, 27–37 fa.

Zosime (?) _fusiformis_, nov. sp. Off Red Cliff, 35 fa.

—— _spinulosa_, nov. sp. Off Hartlepool.

*_Bradya typica_, Boeck. Four specimens, off Hartlepool; sandy bottom.

Spio brunnea, nov. gen. et sp. Off Hawthorn, 27 fa.; sandy bottom.

*_Amymone falcata_, Norman. Off Marsden, 25 fa.; off Robin Hood's Bay, 35 fa.

—— _longimana_, Claus. One specimen, taken off Hawthorn, 27 fa.

*—— _sphærica_, Claus. One specimen, off Red Cliff, about 35 fa.

Pterothrix sordida, nov. gen. et sp. 20 miles off Sunderland, 45 fa.; muddy sand: and 5 miles off Hartlepool; sand.

Tetragoniceps longiremis, nov. gen. et sp. In 30 fa., off Staiths and Robin Hood's Bay.

*_Stenhelia rostrata_? (Claus). In 35 fa., off Red Cliff and Robin Hood's Bay.

—— _hispida_ (Norman). Off Marsden, 30 fa.

—— (?) _ima_, Brady. Off Marsden, Seaham, Staiths, and Red Cliff, 20–30 fa.

*_Ameira longipes_, Boeck. 20 miles off Sunderland, 45 fa.; and off Staiths, 35 fa.

—— _curticornis_, nov. sp. Off Marsden, 30 fa.; 20 miles off Sunderland, 45 fa.

Idya furcata (Baird). Occurred more or less commonly in all the dredgings.

Delavalia reflexa, nov. sp. 5 miles off Hartlepool, sandy bottom.

—— _robusta_, nov. sp. Off Staiths and Robin Hood's Bay, 30–35 fa.

Laophonte dubia, nov. sp. Off Marsden, 30 fa.; off Hartlepool.

—— _Hodgii_, Brady. Off Hawthorn, 27 fa; and off Hartlepool.

Cletodes pectinata, nov. sp. Off Sunderland, Seaham, Hartlepool, Red Cliff, and Robin Hood's Bay, in depths of 20–45 fa.

—— _propinqua_, nov. sp. Off Marsden, 25 fa.

—— _longicaudata_, nov. sp. 5 miles off Hartlepool; sandy bottom.

—— _subnigra_, nov. sp. Off Robin Hood's Bay, 35 fa.

Harpacticus chelifer (Muller). Off Marsden, 25 fa.; muddy sand.

—— _crassicornis_, nov. sp. Off Robin Hood's Bay, 35 fa.

Zaus ovalis (Goodsir). Off Staiths and Red Cliff, 30–35 fa.

Alteutha bopyroides, Claus. Common in all the dredgings.

Thalestris longimana, Claus. Dredged off Scarborough.

—— _helgolandica_, Claus. 6 miles off Hawthorn, 27 fa.

—— _rufocincta_, Norman. Off Hawthorn and Red Cliff, 27–35 fa.

*_Dactylopus flavus_, Claus. Off Hawthorn, Red Cliff, Staiths, and Robin Hood's Bay, 27–35 fa.

—— _tisboides_, Claus. Off Red Cliff and Robin Hood's Bay, 30–35 fa.

Dactylopus tenuiremis, nov. sp. 20 miles off Sunderland, 45 fa.; and off Red Cliff, Staiths, and Robin Hood's Bay, 30–35 fa.
—— *nanus*, nov. sp. 20 miles off Sunderland, 45 fa.; muddy sand.
—— *cinctus*, Claus. Off Red Hill, 35 fa.
Rhizothrix curvata, nov. gen. et sp. Off Robin Hood's Bay, 35 fa.
Jurinia minuta, nov. sp. Off Hawthorn, 27 fa.
Cyclopicera nigripes, nov. sp. In many dredgings, 3–5 miles off shore, in depths of 20–35 fa.
*_Notodelphys agilis_, Thorell. 1 specimen, off Hawthorn, 27 fa.
Lichomolgus fucicolus (Brady). In several dredgings from Marsden to Scarborough, 20–35 fa.
—— *liber*, nov. sp. Off Marsden, Scarborough, and Hawthorn, 20–27 fa.
—— *Thorellii*, nov. sp. Off Marsden, Hawthorn, and Robin Hood's Bay, 20–35 fa.
*_Artotrogus orbicularis_?, Boeck. Off Red Cliff, Staiths, and Robin Hood's Bay, 20–35 fa.
Dyspontius Normani, nov. sp. 3 specimens taken, 6 miles off Hawthorn, 27 fa.; sand.
Solenostoma scutatum, Brady and Robertson. Off Red Cliff, Staiths, Robin Hood's Bay, and Hawthorn, 27–35 fa.
Ascomyzon calvum, nov. sp. Off Staiths, 30 fa.
—— *ornatum*, nov. sp. Off Scarborough and Robin Hood's Bay, 16–35 fa.

The number of Copepoda noted in this list is 63, of which 28 are new to science, and 11 (marked here with an asterisk) are hitherto unrecorded as British species. It is but right, however, to add that several of these, though undescribed, were previously known to us. Still the result of the dredging in this department is extremely interesting, more especially in the considerable number of new species which it has brought to light belonging to the curious groups called by Thorell Pœcilostoma and Siphonostoma. The list of marine Copepoda published by Mr. Brady in 1872, in the 'Natural-History Transactions of Northumberland and Durham,' and including all then known as inhabiting the shores of those two counties, both littoral and pelagic, comprised only 49 species; so that our present list of 63 species taken over an area of similar extent, and from dredged material only, must, we think, be looked upon as highly satisfactory.

The dissection and delineation of these minute creatures is extremely tedious, and we have not as yet been able to complete the work so far as to warrant us in giving descriptions of the various new species.

On the Polyzoa, Hydrozoa, and Spongozoa. By the Rev. A. M. NORMAN, M.A.

POLYZOA.

Scrupocellaria scruposa (*Linn.*).
—— scabra (*Van Ben.*).
Cellularia Peachii, *Busk.*
Menipea ternata (*Ellis & Sol.*).
Bugula avicularia (*Pallas*).
—— purpurotincta, *Norman.*
—— flabellata (*J. V. Thompson*).
—— Murrayana (*Bean*).
—— fruticosa, *Packard.*
Flustra foliacea, *Linn.*
—— truncata, *Linn.*
Carbasea papyrea (*Pallas*).
Gemellaria loriculata (*Linn.*).
Membranipora pilosa (*Linn.*).
—— Flemingii, *Busk.*
Lepralia reticulata, *Macg.*
—— auriculata, *Hassall.*
—— concinna, *Busk.*
—— linearis, *Hassall.*
—— ciliata (*Linn.*).
—— nitida (*Fabr.*).
—— Peachii, *Johnst.*
—— ventricosa, *Hassall.*
Cellepora avicularis, *Hincks.*
—— ramulosa, *Linn.*
—— dichotoma, *Hincks.*
Crisia eburnea (*Linn.*).
—— denticulata (*Lamk.*).
Crisidia cornuta (*Linn.*).

HYDROZOA.

Hydractinia echiuata (*Fleming*).
Eudendrium ramosum (*Linn.*).
Tubularia indivisa, *Linn.*
—— coronata, *Abildgaard.*
Clytia Johnstoni (*Alder*).
Obelia geniculata (*Linn.*).
—— longissima (*Pallas*).
Campanularia Hincksii, *Alder.*
—— verticillata (*Linn.*).
Lafoea dumosa (*Fleming*).
—— pocillum, *Hincks.*
Calycella syringa (*Linn.*).
Filellum serpens (*Hassall*).
Coppinia arcta (*Dalyell*).
Halecium halecinum (*Linn.*).
—— Beanii, *Johnston.*
Sertularella polyzonias (*Linn.*).
—— tenella, *Alder.*
Diphasia rosacea (*Linn.*).
—— attenuata, *Hincks.*
—— fallax (*Johnston*).
—— tamarisca (*Linn.*).
Sertularia filicula, *Ellis & Sol.*
—— abietina, *Linn.*
—— fusca, *Johnston.*
Hydrallmania falcata (*Linn.*).
Thuiaria articulata (*Pallas*).
—— thuia (*Linn.*).
Plumularia pinnata (*Linn.*).
—— setacea (*Ellis*)
—— Catharina, *Johnston*
—— frutescens, *Ellis & Sol.*

SPONGOZOA.

Grantia ciliata, *Johnston*
Polymastia robusta, *Bow.*
—— mamillaris (*Johnston*).
Microciona fictitia, *Bow.*
Hymeniacidon coccineus, *Bow.*
—— virgulatus, *Bow.*, n. sp.
Hymeniacidon ficus (*Johnston*).
Halichondria panicea, *Johnston.*
—— virgea, *Bow.*, n. sp.
Isodictya lurida, *Bow.*
Spongionella pulchella (*Sowerby*).

Among the Polyzoa is *Bugula fruticosa* of Packard*, first described by Packard from Labrador, and subsequently by Smitt from Spitsbergen and Finmark, but not previously found in our seas. I entirely agree with Smitt in considering it to be a form, though a very interesting one, of *Bugula Murrayana.* It differs from the ordinary state of that species in being more delicate in structure, the branches and branchlets much narrower, commonly with only one or two rows of cells, and the cells armed with only few spines, typically one only at the superior and outer angle.

The Hydrozoon *Lafoea pocillum*, Hincks (Hist. Brit. Hydr. Zooph. p. 204, pl. xi. fig. 2), is a recently described species, which has not previously been found on the east coast. Its known habitats were Labrador and Oban.

Two Sponges are pronounced by Dr. Bowerbank to be undescribed, and subjoined will be found descriptions which have been drawn up by that gentleman. He has named the species *Hymeniacidon virgulatus* and *Halichondria virgea.*

"*Halichondria virgea*, Bowerbank, n. sp.

"Sponge massive, sessile, more or less nodulous. Surface smooth. Oscula simple, dispersed. Pores inconspicuous. Dermal membrane abundantly spiculous; tension-spicula acuate, very long and slender, numerous, fasciculated; retentive spicula bidentate, equianchorate, large, few in number, and the same form, small and numerous. Skeleton—rete more or less regular; fibres rarely multispiculous, seldom more than trispiculous; areas large; spicula subfusiformi-acuate, basally spinous. Interstitial membranes spiculous; spiculæ same as those of the dermis; tension-spicula of rare occurrence; retentive spicula rather numerous.

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* *Menipea fruticosa*, Packard, List of Labrador Marine Animals, p. 9, pl. i. fig. 3, = *Cellularia quadridentata*, Lovén, MS. 1834 (*fide* Smitt), = *Bugula Murrayana* forma *quadridentata*, Smitt, Kritisk Förteckning öfver Skandinaviens Hafs-Bryozoer, p. 292, pl. xviii. figs. 23–27.

"Colour, in the dried state, dark purple.
"*Hab.* Coast of Durham, 30 to 35 fathoms (*Rev. A. M. Norman*).
"Examined in the dried state."

"*Hymeniacidon virgulatus*, Bowerbank, n. sp.

"Sponge virgultose, slender. Surface smooth. Oscula simple, dispersed. Pores inconspicuous. Dermis abundantly spiculous; spicula acuate, slender, same size as those of the skeleton, dispersed. Skeleton rather open and cavernous; spicula acuate, long and slender.
"Colour, in the dried state, cream-white.
"*Hab.* Coast of Durham, in 20 to 30 fathoms (*Rev. A. M. Norman*).
"Examined in the dried state."

Report on Observations of Luminous Meteors during the year 1874–75, *by a Committee, consisting of* James Glaisher, *F.R.S., of the Royal Observatory, Greenwich,* R. P. Greg, *F.G.S., F.R.A.S.,* C. Brooke, *F.R.S.,* Prof. G. Forbes, *F.R.S.E.,* Walter Flight, *D.Sc., F.G.S., and* Prof. A. S. Herschel, *F.R.A.S.*

The operations of the Committee during the past year were restricted to collecting and recording occasional observations of meteors, without renewing periodical requests to observers to watch for the meteor-showers of best known dates and characters of annual recurrence. The list of collected accounts of luminous meteors is therefore less ample, but not less remarkable and important, than in former years. The falls of aerolites (as will be seen in the concluding Appendix) which have been placed on record since the last Report are more than ordinarily numerous and interesting. A mass of meteoric iron fell on the 24th of August, 1873, at Marysville, California, and is one of the very few metallic irons the actual descent of which has been witnessed. In the following month, on the 23rd of September, 1873, a number of meteorites fell near Khairpur, in the Punjab; and it is also related that in the month of December in the same year, while the British army halted on the banks of the Prah, an aerolite fell in the market-place of Coomassie, and was regarded by the native population as a portent of evil. On the 14th and 20th of May, 1874, aerolites fell at Castalia, in North Carolina (U.S.A.), and at Virba, in Turkey, the last of which was noted in the last Report; and examinations of both of these meteorites have now been made. The last stone-fall of the past year took place near Iowa (U.S.A.) on the 12th of February, 1875; and of this meteorite also special analyses were made in the United States, of which some unforeseen results were lately announced by their author, Mr. A. W. Wright, as will be described in the last part of this Report. In comparison with meteoric irons, it was found that this meteorite gave off, by gentle heating in a vacuum, carbon oxides as occluded gases in greater abundance than hydrogen, which is the principal gaseous constituent of meteoric irons; and it was observed that the electric spectrum of the gaseous products resembled very closely that found most frequently in comets, and even in one condition to exhibit most distinctly the green nitrogen line coinciding with a conspicuous line in the sun's corona. A meteor of unusual size appeared over Victoria, in Australia, on the 14th of

April last, which if not aërolitic was yet of the largest class, and detonated with a violent explosion. Further remarks in the same Appendix describe recent researches on meteorites, and some new links which they establish between aerolites and terrestrial rocks.

In England no detonating meteor has been recorded since the last Report; and the brightest meteor that was observed occurred on the 1st of September last, taking its course over the north of England or Scotland, where clouded skies must have prevailed, as its flash was like that of lightning even in Cornwall, where, as in Lancashire, its bright luminous streak remained visible, at no great apparent altitude, among the northern stars of the Great Bear. Other bright meteors occurred also on the 2nd and 16th of September, on the 11th of October, on the 17th of December, and subsequently on the 9th of March, 12th of April, and 2nd and 4th of May in this year, of several of which duplicate observations are recorded in the lists of the first two Appendices of this Report. A meteor burst with a loud detonation over Paris and its neighbourhood on the 10th of February last, which was of great size and brilliancy, and left a cloud-like streak of light on its track for more than half an hour. No duplicate observation of it was obtained in England; but from the numerous French descriptions of its appearance, its real path and height may be expected to have formed at the present meeting in Nantes of the French Scientific Association a subject of examination and discussion. Another fireball, according to French scientific journals, fell at Orleans on the 9th of March, and of this two good observations appear to have been obtained in England (in London and in Essex), which may assist to determine its real height.

During the annual meteor-showers of the past year very unfavourable weather generally prevailed for recording meteor-tracks, and few meteors were seen on those nights when the usual expectations of their appearance were entertained. On the 19th of October and 12th of December, 1874, and on the 19th–21st of April, 1875, the annual star-showers of those dates were scarcely perceptible, or were represented by so few conformable meteors as to make the scarcity of the October, December, and April star-showers during the past year a marked feature of their periodical display, and no appearance of the January meteors could be observed on account of obstinately cloudy skies. The August star-showers of 1874 and 1875 were, however, of great brilliancy, and afforded a great number of excellent observations. Duplicate descriptions of some of the meteors were obtained, and the radiant-point was noted, its position appearing to have been this year more confined to the normal place near η Persei than it had been recently observed. Descriptions of these meteor-showers are added in the third Appendix of this Report.

A thorough examination of all the observations collected by the Committee since the publication of the Meteor Atlas in 1867, with the view of extending and correcting the list of general and occasional meteor-showers which it embraced, from the best data furnished by recent observations, has been continued with satisfactory results under the care and direction of Mr. Greg; and the projection of all these useful materials is now nearly completed and exhibited on maps. A supplementary Table of radiant-points contained in the pages of this Report represents the results of his examination; and a number of interesting consequences are drawn from them of the position and identity of some star-showers, which had been a subject hitherto of questions and discussions.

The scattered radiant-region belonging to the August meteors in Cassiopeia and Perseus appears to be accounted for by a distinct radiant-point in Cassiopeia, of which the principal date coincides only partially with the 10th of August, and whose shower again presents a prominent and distinct appearance on the 23rd of that month. Most of the general meteor systems described in the former Atlas are found to be confirmed, and some very distinct radiant-points not previously recorded have at the same time been added to its list.

APPENDIX.

I. Meteors doubly Observed.

On September 1st, October 11th, and December 17th, 1874, and on April 12th and May 2nd, 1875, accounts of the appearance of large meteors were received, which had been pretty generally observed, and of which from their magnitude it may be hoped that more abundant particulars will be obtained. The following descriptions of the first two of these large meteors were collected from published sources by Mr. Wood, together with some other appearances of large meteors and meteor-showers of interest during the past year. Mr. Wood's observation of the fireball of April 12th, 1875, and those relating to the other doubly observed meteors above mentioned, will be found in the fireball list of the next Appendix, together with some examples of doubly observed shooting-stars during the bright shower of the August meteors in 1874. It has not been attempted to submit these comparative observations to regular reduction and calculation, partly as those of the large meteors are too uncertain to afford useful determinations of their real heights, and (in the case of the shooting-stars) in the expectation that a closer examination of the descriptions received of the August meteor-shower in 1874 will continue to furnish further examples of them of which the present may be regarded as instances of only the most conspicuous occurrence. Among the few records of the periodical meteor-showers that have been received (without solicitations from the Committee), during the past year, no other cases have presented themselves in which determinations of a meteor's real height might be obtained by the combination of distant observations.

Newspaper Accounts of Meteors.

Aughton, Lancashire.—" A large meteor seen September 1st, 8.49, in the S.S.W., descended the west margin of the Milky Way. Trended a little more west. Train of light 25° long, lasted one minute."—*Times*, Sept. 5.

Louth.—Meteor moved from S. to N.

Bristol.—" Meteor appeared 3° under η Ursæ Majoris. W. to E."—*Times*, Sept. 3.

Birmingham.—" About 8.15 P.M. on Sept. 1st a bright meteor emerged from the Constellation of the Great Bear, and took a S.W. course. The period of transit was several seconds, but the splendid light left in its track illuminated the heavens for a considerable time."—*Birmingham Daily Post*, Sept. 3. [For descriptions of this large fireball at Bristol and at Bude, Cornwall, see the List in Appendix II.]

Nottingham.—Meteor of Sept. 2nd, 10.53. See 'Times,' Sept. 4th.

Birmingham.—October 11th, 8.55. " A bar of fire as even as a measure, 4 or 5 yards long and 2 inches thick, in a horizontal position. It was very bright, and remained so for a minute and a half. It appeared in the N.E."

Tipton.—October 11th, $8^h\ 55^m$. "Meteor seen as a brilliant white body of the size of a 68-lb. shot. It started a little to the right of the North Star, taking a downward and rapid flight; then changing its course in an upward curve, in the direction of the Pleiades, with a much slower motion, lighting up the neighbourhood, and leaving a luminous train throughout its course, visible 6 minutes."—*Daily Post.*

A meteor similar to the one described above was observed at almost the same time at Leeds, near Maidstone, Kent. "At the end of its flight it exploded with a loud noise, so loud that the informant described it as louder than the loudest thunder he ever heard."—*Birmingham Daily Post.*

Asserted meteor shower Oct. 15, "between 12 P.M. and 1 A.M.; meteors at the rate of fifty per minute at least."—*English Mechanic*, Oct. 23, page 158, letter 20374.

"The inhabitants of Valparaiso were in a terrible state of alarm on the 14th ultimo [November 1874]. A bright star and full moon appeared at middle day, notwithstanding the fact that the sun was shining brightly at the time. The ignorant amongst the populace thought that an earthquake was about to take place. Nothing of the sort, however, occurred."—*Birmingham Local Newspaper*, Dec. 1874.

"Large meteors were seen during the recent clear nights in different places in France—at Havre on the 12th, and at Paris on the 10th. The Paris meteor was seen at two o'clock in the morning; the direction was not specified, but the colour was green. The Boulevard St. Michel appeared as if it were illuminated. The Havre meteor was very large, going with an immense velocity from S.E. to N.W."—*Nature*, April 22nd, 1875.

"A beautiful meteor was seen at Tottenham Lock on June 3rd, at 8.40 P.M., rather to the east of south, about 30° from the horizon. This is very close to Spica."—*English Mechanic*, June 11th, page 328, no. 533.

"At Clapton a splendid meteor was observed at 8.39 P.M. on June 3rd, due south, slow speed, taking a south-westerly course. Meteor brilliant, whiter and much brighter than Jupiter, which looked faint in comparison."—*English Mechanic*, June 11th, page 328.

"Great detonating meteor seen at Melbourne, April 14th, 1875 (see the note below)"*.—*W. H. W.*

To the above list of newspaper accounts of large meteors collected by Mr. Wood may be added the following two accounts in 'Nature' of Oct. 15th, 1874 (vol. x. p. 482), of the remarkable fireball of October 11th, last year. A singularity in the meteor's motion, with slow speed on a deflected course at last, appears to have been observed both at Tipton (as above) and at Rainhill; but it is doubtful if motions of the persistent streak, left for some minutes in a bright patch at the point where the meteor disappeared, may not account for the very singular change of motion there, which the nucleus itself, in two of these observations, is described to have presented.

"BRIGHT METEORS.

"At 8.55 this evening a party of six observed a meteor in the constellation Aries, or below it, which emitted light sufficient to cast a bright gleam on the neighbouring trees. The body of the meteor shot rapidly along a course extending about 20°. It then seemed to explode suddenly, and its track was luminous for a short time. The granular *débris* of the meteor continued to pursue, with very much retarded velocity, a path slightly deflected from its former course: it continued to do so for several degrees; and it was, I think, fully a minute after the explosion that several of us almost simultaneously exclaimed 'It is falling.' It resembled the expiring light of one globe of a rocket charged with golden rain. The falling motion was very slow. I think it was visible for two minutes after the explosion; but though we tried more than once to consult our watches, the light was insufficient."

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* Communicated by Mr. W. H. Wood.—A paragraph from 'The Illustrated Australian News' of May 17th, 1875, is added by Mr. Wood, the substance of which, relating also to an engraving of the meteor which accompanies the original notice in the Australian journal, is included in Dr. Flight's review of recent aerolitic meteors (Meteorites, Part I.) in the concluding Appendix of this Report.

"Henry H. Higgins."

"Rainhill [Sunday], Oct 11, 1874."

"An exceedingly brilliant meteor was seen here about 8.50 on Sunday evening, which was so bright that it attracted general attention, the light from it being as strong as an unusually bright flash of lightning, but more white. On looking up I saw, near the zenith, a long, almost straight and uninterrupted ribbon of light, somewhat pointed at the end towards the north-east. After watching it for some time, and noticing that it retained its brilliancy, I began slowly counting, and counted up to twenty before there was any noticeable diminution of luminosity. The last portion visible was the end opposite the pointed end, which appeared as a faintly luminous patch as large as the apparent disk of the moon. I consider that, from its first appearance, it was visible from 80 to 100 seconds. "A. Balding."

"Wisbech [Sunday], Oct 11, 1874"

A bright fireball was also seen in Hampshire on the 16th of September, 1874, of which the journal 'Nature' contained the following description:—

"Meteor.

"The following is an account of a brilliant meteor which appeared at 8.53 p.m. on Wednesday, Sept. 16:—

"Size: about four times that of Jupiter.

"Colour: blue, with a red tail.

"Brightness: throwing a shadow deeper than that of a full moon.

"Angular measurement of tail. from 12° to 15°.

"Duration: about 15″.

"Direction of course: N.W.

"Zenith distance of point of disappearance: 75°.

"The brilliancy of the tail threw a red light on the surrounding landscape."—*Nature*, Sept. 24th, 1874. "G. H. Hopkins."

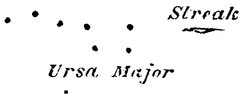
"Bisterne Close, Burley, Hants, Sept 16."

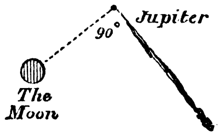
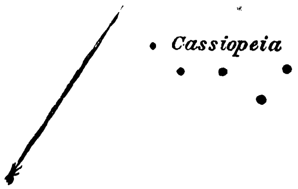
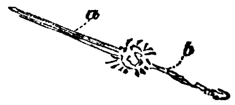
II. Large Meteors.

The largest fireball seen in England during the past year appears to have been that of September 1st, 1874. Some descriptions of this fireball are given in the last, and in the list at the end of this Appendix. Of the remaining fireballs in the list but little general notice appears to have been taken; but it is assumed, with considerable probability, that the two seen in England on the 9th of March and 12th of April, 1875, coincide with large fireballs seen in France on those dates, of which sufficient particulars for comparison with these accounts have not yet been received. Of the unusually large meteor of February 10th, 1875, generally observed in France, numberless accounts, it is reported ('Nature,' vol. xi. p. 413), were received at the Ob-

OBSERVATIONS OF LARGE METEORS, AND DOUBLE OBSERVATIONS OF SHOOTING-STARS, 1874–75.

Date.	Hour (G. M. T. or local time).	Place of Observation.	Apparent Magnitude.	Colour.	Duration.	Position, or Apparent Path.	Length of Path.	Direction or Radiant-point.	Appearance, Remarks, &c.	Observer and Reference.
1870. Sept. 28	h m s Between 7 20 and 7 30 p.m.	Clapton (London) [and Ashby-Brigg, Lincolnshire].	[=Venus]	Intense gold colour.	....	$\alpha=$ $\delta=$ Descended between the tail of the Bear and Arcturus.	To near the horizon.	Fell vertically	Nucleus like an elongated drop; burst as it approached the horizon with a profusion of sparks. (Seen also at Bushey, Watford, like a magnesium light, bursting into three green and three white stars. The flash of light was noticed by Mr. Lucas at the Radcliffe Observatory, Oxford; see these Reports, 1873, p. 373.)	J. C. Jackson. [W. Darby.] 'Astronomical Register,' November 1870 (misprinted in the former Report, "September 1870").
1874. July 28	8 41 p.m.	Writtle, Chelmsford (Essex).	>♃	Pale violet colour.	3 seconds	From 219°+13° to 185 + 2	....	....	Followed by a short yellow train and yellow sparks at the end of its course. Seen by another observer to rise almost from the horizon at its first appearance.	H. Corder.
Aug. 5	About midnight.	Mysore, India.	Large meteor, very brilliant.	....	....	....	....	....	Exploded with a loud noise; caused a superstitious terror among the natives of Mysore.	'Madras Times,' Aug. 11th. 'Astronomical Register,' November 1874.
10	10 52 15	Newcastle-on-Tyne.	>1st mag.*	Orange-yellow.	1·5 second	From 321°+15° to 310 − 5	20°	Perseïd	Two fine meteors following each other nearly together, leaving streaks for about 3 seconds. Several others nearly at the same time.	A. S. Herschel.
10	10 52 45	Ibid.	>1st mag.*	Orange-yellow.	1·5 second	From 324°+ 7° to 312 −13	20°	Perseïd		
10	10 55 30	York	>1st mag.*	....	0·5 second	From 330°+57° to 300 +47	15°	....	Left a streak. [This and the next meteor identical with the last pair.]	J. E. Clark.
10	10 55 30	Ibid.	=♃	....	0·7 second	From 333°+38° to 316 +50	16°	....	Left a magnificent streak for 8 seconds. Four other meteors in 2 minutes.	
10	11 5 0	Newcastle-on-Tyne.	1st mag.*	Orange-yellow.	....	Passed across α [? β] Aquarii.	....	Directed from ½ ($\beta\,\mu$) Pegasi	Left a streak for 2 seconds. Perseïd (?); position of apparent course not well observed.	A. S. Herschel.
10	11 8 0	York	=♃	....	1·0 second	$\alpha=$ $\delta=$ From 350°+51° to 307 +27	33°	....	Left a streak. [Identical with the last.]	J. E. Clark.
10	11 27 0	Newcastle-on-Tyne.	=Sirius	White	1·5 second	From 311°+36° to 301 + 7	....	Perseïd	Left a streak brightest in middle of its course for 4½ seconds.	A. S. Herschel.
10	11 30 0	York	=Venus	Yellow, then red.	0·5 second	From 261°+68° to 236 +41	28°	....	Left a streak for 2 seconds. [Identical with the last.]	J. E. Clark.
10	11 32 15	Newcastle-on-Tyne.	>Sirius	White	1·5 second	From 334°+48° to 307 +11	40°	Perseïd	Left a long streak brightest in the middle of its course for 8 seconds.	A. S. Herschel.
10	11 34 0	York	=♃	....	0·5 second	From 260°+80° to 250 +65	17°	....	Left a streak for 4 seconds; Perseïd. [Identical with the last meteor.]	J. E. Clark.
10	11 44 p.m.	York	=Venus	....	0·5 second	$\alpha=$ $\delta=$ From 31°+32° to 29 +24	9°	Perseïd	Left a streak 7 seconds	J. E. Clark.
10	12 6 0	Birmingham	=2nd mag.*	Blue	0·5 second	From 176°+75° to 190 +62	....	Radiant η Perseï	....	W. H. Wood.

Date.	Hour (G. M. T. or local time).	Place of Observation.	Apparent Magnitude.	Colour.	Duration.	Position, or Apparent Path.	Length of Path.	Direction or Radiant-point.	Appearance, Remarks, &c.	Observer and Reference.
1874. Aug. 10	h m s 12 7 30	Newcastle-on-Tyne.	=2nd mag.*	Yellow	1 second	From ζ Cygni to 3° preceding ε Delphini.	....	....	Left a streak for 2 seconds. Time uncertain to half a minute.	A. S. Herschel.
11	10 41 0	Birmingham ...	=1st mag.*	Yellow	1 second	From 33°+66° to 27 +72	15°	Perseïd; near the radiant-point.	[The Birmingham observations independent; accord perfectly with the next, at Tooting.]	W. H. Wood.
11	10 41 0	Ibid...............	=1st mag.*.........	Yellow	0·75 second...	From 32°+65° to 25 +70	....			T. H. Waller.
11	10 43 0	Tooting, Surrey.	=1½ mag.*.........	White	....	From 157°+62° to 165 +57	5°..............	Course nearly a prolongation of the next (11h 30m), at Tooting.	Disappeared close to β Ursæ Majoris.	H. W. Jackson.
11	11 30 0	Birmingham ...	=2nd mag.*	....	0·75 second...	From 46°+62° to 45 +65	3°..............	Perseïd; near the radiant-point.	....	T. H. Waller.
11	11 30 0	Tooting, Surrey.	=1½ mag.*	White	....	From 142°+67° to 157 +62	8°..............	Nearly from σ_1, σ_2 Ursæ Majoris	[Two meteors only mapped at Tooting.]	H. W. Jackson.
Sept. 1	About 8 49 p.m.	Bristol...........	Very large meteor.	....	....	Passed across Ursa Major, leaving a streak (visible for several minutes until it was obscured by clouds) 3° under η Ursæ Majoris.	....	....	The light was as intense as that of a vivid flash of lightning. [Seen also at Winchester, behind clouds in the north (motion apparently from S. to N.), by Dr. Flight.]	W. F. Denning, 'Astronomical Register,' October 1874.
1	About 9 0 p.m. (Time by estimation.)	Bude (Cornwall).	Very brilliant meteor.	White; very dazzling.			....	....	The meteor resembled a flash of light falling to the ground. The streak, like the tail of a comet without a head, remained 3 minutes in the star-lit sky, as in the figure, gradually fading away.	E. H. Marshall.
6	About 8 40 p.m.	Bristol...........	= ♃	Passed between β & γ Ophiuchi.	....	α= δ= From 275°+20° to 255 −12	37°	Directed from γ Lyræ	Left a streak almost vertical in the south-west for a second.	W. F. Denning, 'Astronomical Register,' October 1874.
Dec. 17	About 10 25 p.m.	Halifax (Yorkshire).	Fully as bright as Sirius.	....	3 seconds......	In the S.E. Disappeared halfway between Sirius and the horizon.	Began as far eastward from Sirius as that star was from the horizon.	Course nearly horizontal but slightly falling.	Seen through glass panes of a conservatory. No streak visible in the open air. [Perhaps the same meteor as that observed in Paris at 10h (local time), and at Lewes, Sussex, at 10h 30m p.m. See the note from 'Nature,' Dec. 24th, 1874, in the last paragraph of this Appendix.]	Jos. Gledhill, 'Astronomical Register,' October 1875.
1875. Feb. 10	About 5 45 p.m. (Paris time).	Belle Isle, Isle d'Oléron, Nemours, Thiery, Cognac, &c. (France).	Very large meteor	....	....	....	....	....	Leaving a very persistent streak, at first straight, then contorted, visible for half an hour.	Accounts by several observers in 'Comptes Rendus,' vol. lxxx. p. 575 *et seq.*
March 9 & 10.	Evening ...	France...........	Many large meteors seen.	....	....	....	....	....	A 'meteorite' is reported to have fallen at Orleans on March 9th. ('Nature,' vol. xi. p. 396.)	'Nature,' vol. xi. p. 413.
Mar. 9	About 8 0 p.m	Cooper's Hill (Kent).	As bright as Sirius	....	Moved slowly.	Began at a point a few degrees east of Sirius.	....	Descended in a south-easterly direction on a path inclined about 60° to the horizon.	(For Mr. Denning's description of the same meteor at Bristol, see next page.)	H. Macleod. 'Nature,' vol. xi. p. 427.
Apr. 12	8 6 p.m.	Birmingham ...	=Venus	White	1·5 second ...	From λ Coronæ to γ Serpentis.	....	N_8	Perhaps identical with meteors noted on the same date in France, in Paris, or at Havre.	W. H. Wood.

Date.	Hour (G. M. T. or local time).	Place of Observation.	Apparent Magnitude.	Colour.	Duration.	Position, or Apparent Path.	Length of Path.	Direction or Radiant-point.	Appearance, Remarks, &c.	Observer and Reference.
1875. Mar. 9	h m 8 0 p.m.	....	Quite as bright as Venus.	....	Motion exceedingly slow; about 3 seconds.	Passed down the S.E. sky, about 9° W. of Cor Hydræ. $\alpha=$ $\delta=$ From 134°−16° to 144 −26	16°	From Radiant A_5, near α Persei, No. 38 in Greg's general list. [See last year's Report.]	Seen through much haze; left no visible streak on its course.	W. F. Denning, 'Astronomical Register,' May 1875.
Apr. 21	About 1 15 a.m.	Newcastle-on-Tyne.	About = Venus ...	Bright white .	About 1½ sec.		15° or 20° ...	....	Globular nucleus; leaving no sparks nor streak. Apparent course nearly as shown in the sketch.	J. Hopper.
May 4	9 59 p.m.	Ibid	About = ♃	White	About 3 secs.	 Descended obliquely from near the foot of Cassiopeia across Perseus.	30°	....	Meteor without sparks or streak. Apparent course about as represented in the sketch.	Id.
July 28	10 28 p.m.	Regent's Park, London.	Nearly = ♃	....	Shot steadily; moderate speed.	Began at ϵ Pegasi. Disappeared near but below θ Aquilæ.	15° or 16° ...	On a line produced from β η Pegasi.	Probably a Perseïd (or ? Pegasid). Nucleus with very broad brilliant blue train.	T. Crumplen.
Aug. 7	About 10 5 p.m.	Hawkhurst, Kent.	About = Venus ...	Green	About 1½ sec.	From a few degrees below τ Pegasi passed a few degrees below η ζ Aquarii and 4° or 5° further.	....	....	 Expanded to middle of its course, where it diffused a bright green light, and continuing about ½ a second further disappeared abruptly. Left a broad reddish gold-coloured train, about 5° (from a to b), on the middle of its course.	M. S. Hardcastle.
15	8 35 p.m.	Ibid................	A fine meteor; much brighter than Sirius.	Like a brilliantly green star.	....	Halfway between Capricorn and Scorpio.	Short course.	Obliquely downwards	....	Id.

servatory in Paris; and although it is not described as detonating, and no aërolitic fall is ascribed to it in any of the published narratives of its appearance, some determination of its real course, which appears to have been over the western departments of France, must, it may be expected, be derivable from the abundant materials which have thus been collected. In the following communication on a large fireball of the 2nd of May last supplied to the Committee by Mr. Symons, attention is directed to other accounts of the same meteor as seen in Kent and elsewhere; but of these contemporary descriptions of its appearance the Committee has not received any additional particulars.

"The meteor noticed in Kent and elsewhere at $8^h\ 45^m$ P.M. on the evening of the 2nd inst. was seen to advantage by myself and two friends. It passed from S. by E. to E.S.E., from an altitude of about 35° to about 22°. It appeared brighter and larger than Venus, was of a very red tint, broke into fragments just before disappearing, and occupied, as seen here, not seven seconds, as mentioned in the papers, but between three and four."

"W. CLEMENT LEY."

"Ashby Parva Rectory, Lutterworth, May 4th, 1875.

"*To G. J. Symons, Esq.*"

Some meteors of unusual brightness observed in Essex during the early part of this year are thus described by Mr. H. Corder in the 'Astronomical Register' of June 1875 (vol. xiii. p. 145):—"On March 16, at $8^h\ 23^m$, I was startled by a bright light from behind me, and on turning round was just in time to see the disappearance of what must have been a fine meteor. When I saw it it was about the size of Sirius, but had been far brighter. It rose perpendicularly over either β or δ Leonis. I think the former.

"On the 17th, about 9^h P.M., another bright meteor was seen here, but I have received no details of it.

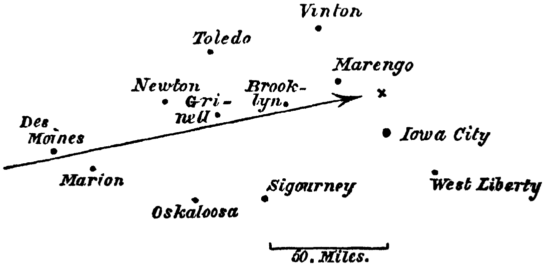
"On April 22nd, at $11^h\ 19^m$, I saw a very beautiful one in the extreme east of Virgo, falling about 4° on each side of the equator from Corona; and though the new moon was shining a few degrees from it, the meteor formed a distinct orange ring or corona in the highest cloud in front of it. It was of a lovely pale-green hue, with a train of sparks; and though of no apparent size, was considerably more brilliant than Venus.

"Another meteor, of a red colour and of short duration, brighter than Jupiter, was seen in the south-west about 25° from the horizon on May 6th at $7^h\ 55^m$."—*H. Corder, Writtle, near Chelmsford, May 8th*, 1875.

The following is the note in 'Nature' (vol. xi. p. 153) on the meteor of the 17th of December last year, referred to in the present list under the observation of the corresponding date:—"On Thursday, December 17th, at 10 P.M., a magnificent falling star was observed in Paris. Its track was to be seen for more than a minute. A correspondent, Mr. J. H. A. Jenner, writing from Lewes [Sussex], states that 'on Thursday evening, the 17th inst., at 10.30, a very fine meteor was seen here. It travelled from north to south at a seemingly very low elevation; and though the moon was shining brightly it was a very brilliant object, being several times the brightness of Sirius. Its colour was yellowish, and it left a long, but not very persistent, bluish-white train. Had the night been dark, it must have been a very splendid object. The point of disappearance was hidden from my sight by houses, but there was no noise attending it.'"

III. Aërolites and Meteor-Showers.

Iowa, United States, America, 1875, Feb. 12th, 10^h 30^m P.M. (Chicago time).—The Committee is indebted to Mr. B. V. Marsh, of Philadelphia, for many contemporary descriptions of this meteor and of the stonefall that accompanied it, from American local journals, of which the accompanying outline map roughly represents the geographical positions, together with the probable line over which the meteor was vertical in its course. The accounts contain descriptions of its appearance at Iowa city, where it was observed by Prof. N. R. Leonard (Iowa St. Univ.), who afterwards examined and described the sites of the meteor's fall at Grinell, Oskaloosa, Vinton, Des Moines, &c., and additional observations of it at Brooklyn and West Liberty are supplied by Mr. Marsh. The apparent size of the meteor as seen at Iowa city was half that of the full moon, and its light appeared at West Liberty as strong as that of full daylight. It presented three separate explosions (attended apparently by as many distinct reports), and a streak of bright light marked its course, described at Grinell as intensely bluish white and at Iowa city as slightly tinged with green; the apparent colour of the nucleus itself at the latter place was that of molten iron, and the whole duration of its visible flight was estimated at about one second. The sound of the report followed the appearance there in two or three minutes, like three blasts of a quarry, accompanied by a rolling or rumbling noise. The explosion at Brooklyn and westward from Iowa city was still more violent. It followed 3^m after the appearance of the meteor (by watch) at Grinell, and at an interval of about 5^m at Searsborough (10 miles south of Grinell). Its description at Washington is as of a rumbling earthquake sound lasting a minute, and shaking houses plainly. At Vinton it consisted of three or four cannon-like reports, followed by a sound resembling that of a railway-train crossing a bridge. The meteor and its report were seen and heard over a space 125 miles in extent from E. to W., and over half as wide a space from N. to S. Fragments, varying in size from a few lbs. to 150 lbs., were found at Homestead and other places in the neighbourhood of Brooklyn and Iowa city, having excavated to a great depth both earth and snow upon which they fell. The point marked × in the map is the site of one of the first fragments found, about 6 lbs. or 7 lbs. in weight, in N. lat. 41° 46′, W. long. 92° 0′.



Descriptions of this meteorite and of another stonefall which took place a few months later in Zsadány in Hungary, will be found in a review of such occurrences, and of the principal investigations that have been made with regard to them during the past year, in the notices on Meteorites (Part I., pp. 240, 243) at the end of this Report.

The August Meteor-shower in 1874.—The shower was partially observed near Chelmsford, Essex, by Mr. H. Corder, with the following results as to the numbers seen; but the cloudy state of the sky prevented any appearance of the shower from being visible on the night of the 10th.

	August 2nd, 1874, $9^h 50^m$ to $10^h 50^m$.	August 5th, $13^h 36^m$ to $13^h 45^m$.	August 6th, $9^h 54^m$ to 11^h.	11^h to $11^h 40^m$.
No. of meteors mapped .	8	5	31*	6*

On the night of August 11th, with a favourable view of the sky. Mr. Corder, watching alone (as on the former nights), counted the following numbers of shooting-stars in the half-hours ending at

	9^h–10^h.	$10^h 30^m$	11^h	$11^h 30^m$	12^h.	$12^h 30^m$	Total in $3^h 30^m$.
No. of meteors counted .	13	17	22	22	17	13	104

Three of these meteors were as bright as Jupiter, the brightest appearing at $10^h 35^m$ P.M. in Cassiopeia; 82 left streaks, including all of the 1st, nearly all of the 2nd, and a great proportion of the 3rd mag. shooting-stars. Twelve meteors were unconformable, or obviously not directed from the radiant-point in Perseus, and the length of path varied from ½° to 30° (in the case of a large one overhead at $11^h 5^m$ P.M.). The prevailing colour of the meteors from Perseus was orange. Their general centre of divergence was near the cluster χ in Perseus, extending also to Cassiopeia. On August 2nd most of the meteors diverged from ϵ Pegasi; and on the 6th the points of radiation were very various, belonging chiefly, however, to the shower from Perseus.

Mr. J. E. Clark obtained a view of the shower at York on the night of the 10th, mapping 40 meteor-tracks between $10^h 7^m$ and $11^h 55^m$ P.M., and together with Mr. E. Grubb counting the following numbers in the successive half-hours of the watch ending at

	$10^h 45^m$.	$11^h 15^m$.	$11^h 45^m$	$11^h 45^m$ to 12^h.	Total in $1^h 45^m$.
Numbers of meteors seen by two observers	37	19	35	18	109

The following numbers of meteors of different magnitudes were mapped:—

Brightness......	= ♀ or ♃.	>1st mag.	=1st do.	=2nd do.	=3rd & 4th do.	Total.
No. of meteors mapped......	7	4	14	10	4	39

Between $10^h 45^m$ P.M. and midnight on the 10th of August the tracks of these August meteors were mapped by Prof. Herschel at Newcastle-on-Tyne in the following numbers, during the half-hours of the watch ending at

---

* Of these meteors (mostly Perseïds, and 14 with trains) the numbers of various brightnesses were:—

1st	2nd	3rd	4th and 5th magn. stars.
5	11	10	11

	$11^h\ 15^m$.	$11^h\ 45^m$.	$11^h\ 45^m$ to 12^h.	Total in $1^h\ 15^m$.
No. of meteors mapped.....	20	17	7	44

Of the different magnitudes of brightness there were observed the following numbers:—

Apparent brightness...	♃ or ♀.	Sirius.	1st mag.	2nd do	3rd do.	4th & 5th do.
Nos. of meteors seen	2	5	8	10	11	10

Mr. W. F. Denning's view of the shower on the 10th, at Bristol, is thus described in a letter in the 'Astronomical Register' (September 1874), containing notes of his observations of the display. The night of the 10th was fine and moonless. The meteors were watched almost continuously for four hours, from $10^h\ 45^m$ to $14^h\ 45^m$, and 281 meteors were observed. Thirty-two of these were as bright or brighter than 1st-magnitude stars; 252 were Perseids, and almost all (with *very* few exceptions) left persistent streaks, lasting, however, rarely more than about 2 seconds. On the night of the 11th, although, as on the 9th, the sky was generally unfavourable for observation, a watch of 10^m, in a clear interval, soon after 10 o'clock, presented 12 shooting-stars; and they appeared to be nearly as numerous as on the preceding night. The principal radiant-centre of divergence of the Perseids was between B, C Camelopardi and χ Persei, at R. A. 39°, N. Decl. 58½°; and other radiant-centres in Cassiopeia, Pegasus, and Draco were at the same time in perceptible activity during the shower.

The nights of the 9th and 11th having generally been unsuitable for a watch on account of the clouded state of the sky, it is satisfactory that at one station (Mr. Corder's in Essex) a continuous enumeration of the meteors was possible on the night of the 11th; and by comparison with records on the 10th at the other places of observation, it does not appear that the intensity of the display had very notably diminished. It is not possible from these particulars to determine the time of maximum of the display even approximately, although in point of brightness and numbers the Perseids in August 1874 were probably more conspicuous on the night of the 10th than on the following night. If allowance is made for the absence of the moon, the shower appears to have been one of very considerable intensity, and to have presented an abundance of bright meteors, but scarcely to have exceeded in this respect either of those of the two preceding years, nor to have quite attained the somewhat exceptional brilliancy of the August star-shower in the year 1871.

The October Meteor-shower in 1874.—Fine nights for observing these meteors occurred at Birmingham on the 18th and 19th of October, and a watch for them was continued for one hour on each night by Mr. Wood. Four meteors were seen and mapped between 11^h and 12^h on the 18th, and 9 meteors between $10^h\ 30^h$ and $11^h\ 30^h$ on the 19th, while a further watch of half an hour on this latter night from $11^h\ 30^h$ to 12^h was without result, no more shooting-stars being visible during the continuance of the watch. The meteors mapped radiated principally from O and F_1, $_2$, the two radiants of the October period in Orion and Auriga, but not in sufficient numbers to make the return of these showers conspicuous, or to afford important determinations of their radiant-points from the few representatives of the principal October meteor-shower which were observed. On the night of the 20th the sky was overcast; and, as far as the Committee has learned, no other notes on these dates could, for similar grounds, be obtained at other observing stations where the annual showers of October, November, and December, and of January, April, and August, have hitherto been observed.

November, December, and January Meteor-showers, 1874–75.—In consequence of the accumulating number of meteor observations on the annual dates of the periodic shower, observations of the November, December, and other annual meteor-showers of the past year have not been especially solicited; and the condition of the sky on the returning dates of the above three showers was such that only a widely organized watch could have obtained useful particulars of their appearance. The November and January showers were looked for without success from the prevalence of clouds; and that of the 12th of December, when the circumstances were favourable for its observation, disappointed expectation by an unusual scarcity of the Geminids on the periodic night. With a perfectly clear sky, in the absence of moonlight, one meteor only was visible at Newcastle-on-Tyne in an interval of 45^{m} from $11^{h}\ 30^{m}$ to $12^{h}\ 15^{m}$ on the night of the 12th; and although this small shooting-star was a Geminid, the loss of intensity of the shower since its last periodic return on the 12th of December, 1873, is very conspicuous and striking. A careful record of the meteors of November and December last was kept, however, by the astronomers of the Toulouse observatory in France, where M. Gruey ('Comptes Rendus,' vol. lxxx. p. 56) mapped the tracks of a considerable number of meteors in both months. But few meteors, and those generally unconformable to Leo, were seen on the partially cloudy nights of November 12, 13, and during a fine interval of the following night, from 3^{h} to $4^{h}\ 30^{m}$; and on the morning of the 15th a greater scarcity even of sporadic meteors prevailed, and not a single shooting-star was visible during a very attentive watch. On the nights of the 10th, 11th, and 12th of December, 1874, watch was again kept, and on the first two nights a somewhat plentiful display of meteors was observed. Three observers, watching a quarter of the sky, saw on the night of the 10th 34 meteors in $1^{h}\ 20^{m}$ (average rate of frequency 25 per hour); on the night of the 11th, 17 meteors in 35 minutes (or at the rate of 30 per hour); while on the night of the 12th 4 meteors only were seen in the first and none in two subsequent watches of 10^{m} each, in which the clouds cleared away sufficiently to leave the sky unobscured. The majority of these meteors were conformable to a radiant-point near which (at R. A. 130°, Decl. + 46°) one of great brightness on the 10th appeared stationary; and although this place differs considerably from the usual direction of divergence of the Geminids of this shower, and from the place of its centre observed by M. Tisserand in December 1873 ('Comptes Rendus,' 1873, December 15), yet the general emanation of the meteor-tracks recorded from about this point was very apparent; and as an average radiant-centre of the 11 meteors mapped on the 10th, 7 on the 11th, and 2 on the night of the 12th (or 20 shooting-stars in all), it was very distinctly marked. Several radiant-positions by other observers, closely adjacent to it, will be found in Greg's general list (1874), No. 175. As regards their brightness, the following numbers represent the total of each description which were visible throughout the watch:—

Apparent brightness	1st mag.	2nd do.	3rd do. and under.	Total.
No. of meteors seen in $2^{h}\ 25^{m}$...	18	9	28	55

M. Gruey suggests (and the conjecture well deserves further trial and corroboration) that the radiant-point of the December shower is multiple, and that his new position of it is a special one, which was very perceptible on this occasion.

Mr. Clark watched at Heidelberg for the return of the November meteor-shower, during a partially overcast state (clouds concealing about one half or two thirds) of the sky, on the mornings of the 14th and 15th of November last (1874), for about 25 minutes on each date, and observed a small Leonid and two Taurids on the former, and three brighter Leonids (two of which left enduring streaks) and one unconformable meteor on the latter date. The shower does not appear to have entirely disappeared, and its tendency to reach a maximum on the morning of the 15th rather than on that of the 14th appears still to be sensible in its decreasing phase. At Heidelberg and at Sunderland in England, Mr. Clark and Mr. Backhouse reported the state of the weather at the principal periods of the December and January showers as unfavourable for observations. No observations of the January star-shower in 1875 could, from the general prevalence elsewhere of similarly unfavourable conditions, be obtained.

The April Meteor-shower in 1875.—All the accounts which the Committee has received of observations on this star-shower during the bright moonlight and hazy state of the sky on the nights of the 19th-21st of April last are corroborative of the almost total cessation or disappearance of the shower at the usual time of its annual return. During a watch of $1^h\ 30^m$ on the 19th, and of 1^h on the 20th, Mr. M'Clure, with one assistant at Glasgow, observed only a single meteor (apparently not a Lyraid) on the former night. At Newcastle-on-Tyne the sky was very clear from $10^h\ 50^m$ P.M. until midnight on the night of April 20th, and five meteors, one of which was a small Lyraid, were observed. Two of these were of remarkable length of course and brightness, directed apparently from radiant-points near Aquila, Arcturus, or in the southern hemisphere: but from the brightness of the full moon meteors of smaller brightness than 3rd- or 4th-magnitude stars would not have been visible on the occasion of this periodic watch; and with regard to the disappearance of the shower on the night of April 20th, some evidence of its occurrence may have been visible in foreign countries, of which, on account of the maximum being reached during daytime in England, the observation at English stations could only be very partial, and may in this manner have been quite prevented.

At Birmingham the sky was clear on the 21st, and in the full moonlight, which still prevailed, Mr. Wood observed at Birmingham, at $10^h\ 52^m$, one meteor only (a bright Lyraid) as the result of an attentive watch of $1^h\ 5^m$ for the expected April shower.

Meteor-showers of August 1875.—The stormy and unsettled weather of the early days of this month interfered at almost every station with regular observations, the day and evening of the 10th of August itself being one of most violent thunderstorms throughout the country, and but scattered records of the Perseus shooting-stars were in consequence received. Noticing meteors to be frequent on the night of July 28th, Mr. Crumplen mapped some of their apparent courses in London between 10^h and $10^h\ 30^m$ P.M.; and those of seven proved to be Perseids, with a radiant-point between χ Persei and Cassiopeia. A communication concerning observations of meteors on the 2nd of August was also received by the Committee from Mr. Hind, who relates that between $9^h\ 30^m$ and 11^h P.M. on that evening a number of meteors were remarked, one of them of α Lyræ brightness, the radiant-point of which was "most decided," and its position was found to be at omicron Andromedæ (R.A. 344°, Decl. +41°). The existence of this radiant-point in August was pointed out in the first of Mr. Greg's general lists of radiant-points (Report, 1864, p. 100, No. xxx.), attaching to it the sign EG after its neighbourhood to Heis's radiant-point E *in October* in the constellation Lacerta (German *Eidechse*), which was found by Mr. Greg to be a very persistent and much earlier occurring shower. Although its position was afterwards confirmed (as will be seen in the subjoined Table) and extended to include radiants with more northern declinations in Schiaparelli's and Tupman's lists, yet it appears that the new radiant-point observed by Mr. Hind allies itself more closely to an earlier group, close to the same place, well marked in Schiaparelli's list, and together with some closely adjoining radiant-points forming the only representatives in that list of the well-known meteor-shower of the "Pegasids," diverging about the time of the 10th of August star-shower of the Perseids from near the star α Pegasi. The confirmation which this observation affords of the early occurrences in July and August of "Lacertid" meteor-showers noted in Schiaparelli's list, which were unattested hitherto by other observers, is at the same time a corroboration of special interest from the very sharply-defined and well-recorded date and position of the radiation.

Table of Cepheid, Lacertid, and Pegasid Meteor-showers in July, August, and September.

	Sign.	Duration of shower.	Position of Radiant-point.		Remarks.
			R A.	Decl.	
Heis (Die periodische Sternschnuppen, 1859) and Radiant-list, 1864..	E	Oct 16–31	330°	+50°	
R. P. Greg, Radiant-list, 1864.	EG	Aug 17-Sept 30	333 (from 314, +52 to 347, +47)	+50	
Id. Radiant-list, 1867–68...	E (*c* Lacertæ)	Aug 7–Sept 30	335	+52	
J. F. Schmidt, Radiant-list, 1869	......	Aug. 7–31	347	+51	Continued nearly at the same place in September and October.
G. V. Schiaparelli & Zezioli, Radiant-list, 1871	No. 145	Aug 28	340	+65	No other neighbouring radiant in these months.
	„ 146	Sept 5	321	+60	
	„ 151	Sept. 20	317	+47	
G. L. Tupman, Radiant-list, 1873	„ 52	Aug 22	340	+33	Do.
	„ 54	Aug. 23	334	+48	
	„ 77	Sept 22	345	+61	
E. Weiss, 1869........... ...	......	Aug 12–13	345	+50	Quoted in Tupman's list.
R. P. Greg, Radiant-list, 1872 (and 1874) ..	90 (112) E_1	Aug 6–31 ?	335	+67	(E_1 subradiant of the *Lacertids*, E_2).
	96 (125) E_2	Aug 10–Sept. 30	335	+52	
J. R. Hind, 1875	(*o* Andromedæ)	Aug 2	344	+41·5	Appears to coincide with the two radiants (below) S & Z. 123 and 134.
	No. 98	July 18	332	+35	
	„ 103	July 19	338	+43	
Schiaparelli's & Zezioli's list.....	„ 106	July 19	334	+45	Radiant-region, *Lacerta.*
	„ 123	July 30	335	+40	
	(Average	July 18–30	335	+41)	
Quoted in the Nos. below of Greg's General lists.	No. 100	July 18	342	+23	
	„ 104	July 19	332	+23	Radiant-region, β η μ Pegasi.
	„ 113	July 23	336	+30	
	„ 134	Aug. 4	342	+29	
Greg's General lists, 1872	(Average	July 18–Aug. 4	338	+26)	
(and 1874)	76(95,96)TG	Aug. 3–15	337	+25	Pegasid subradiant.
„ „	67 (97) T_1	Jan. 29–Aug. 24	330 to 345	+14	Near α Pegasi. (Radiant of the *Pegasids.*)

Between 10^h P.M. and midnight on August 9th, 1875, Mr. Waller observed 50 shooting-stars at Birmingham, showing that the shower of Perseids had already reached a considerable intensity on that night. On the following night Mr. Wood observed at the same place a somewhat larger number (as will be seen by his report), and mapped the tracks of 40 meteors radiating, with only one or two exceptions, from Perseus, and a few of them from a branch radiant-point apparently at ϵ Cassiopeiæ. The principal radiant-point in Perseus was at the star η of that constellation—scarcely any of the meteor-tracks prolonged backwards diverging far from this point, and the radiant-point of the remainder, constituting a very small proportion of the whole number, being in the neighbourhood of χ Persei. One of these meteors (at 11^h 39^m 30^s) was as bright as Jupiter; and eight others were as bright as Sirius, or brighter than 1st-magnitude stars. Mr. Wood thus describes the general characteristics of the shower during the period of his observations. The sky was very clear and, from the absence of moonlight, very favourable for obtaining meteor registrations.

1875, Aug 10, P.M. From	to	Hourly numbers Clear sky One observer.	Average position of the radiant-point	Percentage of magnitudes.
10^h	11^h	20 meteors seen	R A 36°, Decl +57°	1st=45 p. ct.
11	12	40 ,, ,,	Perseids 85 per cent.	2nd=27 ,,
				3rd=28 ,,

Predominating colour of the meteors yellow. Eighteen of the forty meteors mapped were described as leaving very persistent streaks, one of these (the last on the regular list, at 12^h 6^m) being a bright meteor from the direction of the well-known concomitant radiant-point of the August shower in Pegasus. On the nights of August 9th and 11th the sky was overcast.

The sky was clear and the meteor-shower was well seen at Sunderland by Mr. T. W. Backhouse on the night of the 10th, from whom the particulars of its appearance noted below have been received. The following is Mr. Backhouse's description of a Perseid of great brightness, which exceeded in magnitude any other meteor of the shower which he observed:—"It appeared at 13^h 24^m [1^h 24^m A.M., August 11th, 1875] $\frac{1}{4}$° to the right of α Aurigæ, and was directed towards θ, disappearing near ν and τ Aurigæ. It increased very rapidly in brightness just before disappearing, becoming brighter than Venus at its brightest, making a bright glow round it. Its tail also increased rapidly in brightness and was of many colours, but its changes were too rapid for me to follow them; purple, however, predominated at first, and afterwards green. After the head disappeared, the tail remained some seconds quite straight (and vertical), and gradually became slightly serpentine—the brightest part (that near the head) lasting at least $4\frac{1}{2}$ minutes, becoming a group of cloudy patches 3° or 4° in extent, and spreading out N. and S. The stars ν and τ were at first at the S. end, and then in the middle of this group. At 13^h 27^m or 28^m I looked at it with my $4\frac{1}{4}$-inch refractor with a low power; it was irresolvable, and like a group of a few large undefined nebulæ, the brightest part at ν and τ Aurigæ." In a watch at intervals between 10^h 20^m and 14^h 20^m, amounting together to 96 minutes, and equivalent to one of 82 minutes in a sky without clouds or twilight, 70 meteors were seen, corresponding (as the number seen in a clear sky by one observer) to an average rate of frequency of 51 meteors per hour. The great majority of the meteors seen in these periods of observation of the shower were Perseids.

Between 12^h and $12^h\ 30^m$ on the night of August 11th, Mr. Greg observed 10 meteors, chiefly Perseids, in an interval of clear sky, at Buntingford, Herts; and four of these were of considerable brightness. The radiant-region was diffuse, extending apparently between α Persei and ε or ι Cassiopeiæ.

General Radiant-lists, and their extension and corroboration by observations (chiefly collected by the Committee since the year 1870).—The numerous observations (principally of the periodical meteor-showers of January, April, August, October, November, and December) communicated during the past six or seven years, since the publication of the Committee's "Atlas of Radiant-points" in the year 1867, which have remained unpublished in these Reports since the year 1870, together with the printed meteor-catalogue of the "Radcliffe Observations," Oxford, for the years 1869–1872, afford abundant materials for revising and correcting, and in some cases for extending the list of Radiant-points included in that Atlas, of which advantage has only been partially taken by Mr. Greg in his most recently published general lists of Radiant-points (see these Reports for 1868, p. 401, the list of the 'Atlas' of meteor-showers, 1872, Table facing p. 109, and 1874, pp. 324–339). The latter list contains all the combined radiant-lists of various observers, and reproduces, with very little alteration, the earlier meteor-shower list of the British Association 'Atlas' in 1867, as the portion of the Catalogue which depends directly upon observations collected by the Committee. By comparison with the more recent observations, Mr. Greg is now enabled to present the following modifications and instances of corroboration of his general list (p. 221) which the above-named continued series of observations are found to afford, and which they suggest as desirable points for verification in the case of a continued collection of occasional meteor-observations for such an object. Several new radiant-points are comprised among these results; and new positions and durations are assigned to several of the formerly established showers, of which the particulars and the general extent will most readily be gathered from the following notes of these comparisons supplied by Mr. Greg. The reference numbers in the first column of the Table correspond to those of the general list in the volume of these Reports for 1874 (p. 324), and to this list and to the older one of 1868 the present Table supplies a five or six years' commentary and continuation. Some radiant-points of the list deserve special notice as having received from the new observations important illustrations. Showers formerly very conspicuous are occasionally unnoticed, or were invisible in the newer observations. Of these showers, B G (G. & H., No. 101) of the "Cygnids" in July and August is an example, having been only very sparingly observed since the year 1870; while an equally marked meteor-shower of July, near the head of Draco, B Z (No. 102), has presented itself with greatest intensity in August as a concomitant of the 10th of August meteors, and during the periods of observation immediately connected with the systematic watches for that shower.

Two well-defined meteor-showers in October and November, and a third in December, the Orionids of October 16th–24th, Taurids of Nov. 2nd–12th, and Geminids of December 10th–14th, appear to be connected together by intermediate meteors, absorbing with the principal radiant-points themselves a large proportion of the sporadic meteors visible in those months. The first two of these showers are in great part contemporary, the shower-radiant in Orion comprising, according to Schmidt, six subradiants in October and November, with an average position at about R.A 83°, Decl. + 11°. The place of its maximum appearance, about the middle of October, is in somewhat greater right ascension and declination (by four or five degrees) than this position; and a comparison of its elements might perhaps be attempted successfully with those of the comet of 1821, I. (radiant-point at 86°, +19°·5), if the nodal date (November 11th) of this comet is capable of being reconciled with the much earlier time of appearance of the Orion shower. In the 'Memorie della Soc. degli Spettroscopisti Italiani' of May 1874, a memoir on the meteors of the 17th–28th of October (1609 meteor-tracks observed by Drs. Heis and Schmidt, Zezioli, and at the Vienna Observatory, between the years 1843 and 1873), by Ludwig Gruber, of Vienna, is inserted, in which the author discusses the apparent radiant-points of this meteoric epoch by projecting the meteor-tracks recorded successively on each single date. The smallest number of tracks (65) occurred on the 20th, and the greatest (284 and 226) on the 22nd and 24th of October; 310 meteors were found to be sporadic, or incapable of reduction to any distinguishable radiant-point. Of the remaining meteors, Dr. Gruber regards 16 radiant-points as having sufficiently well-defined positions to admit of further calculations as regards their orbits. The accompanying list (p. 220) exhibits the dates and positions together with the relative intensities of these several showers, as shown by the percentage numbers of meteors belonging to them on the days when they were most conspicuous. The Table also contains comparisons of their positions with those of already noted meteor-showers in other radiant-lists.

These radiants may be grouped in great part under already recognized displays, as those of the *Orionids* (II. & VIII.), *Muscids* (V., X., XIV.), *Taurids* (VI.), *Castorids*, or *Gemellids* (between Castor and Pollux, IX.), a shower from near β Geminorum (first recorded in that constellation by Herrick from the 20th to the 26th of October, 1839, and observed at the above place, in great intensity, by Zezioli from the 21st to the 25th, and especially on the morning of the 23rd of October, 1868 [*]), *Cassiopeids* (XII.), and *Polarids* (XV.). But certain radiant-points of the list are new to the general Radiant Catalogue of Mr. Greg in the last volume of these Reports, and they are included below (Nos. 194, 195) in the present Supplementary Table of that list. Dr. Gruber's position of the radiant-point XIII. agrees distantly with that of a new radiant-point for the end of October near *o* Piscium, noticed by Mr. Backhouse in 1872, and established by Mr. Greg from several other meteor-tracks in his examination of the recent observations. It may be added that the older radiants RG$_1$, T$_{1, 2, 3}$, and TG$_1$, E$_{1, 2}$, and N$_{11}$ A$_9$, in August, and the October–December showers A$_{15-17}$ near Cassiopeia, have undergone revision by means of the observations up to the year 1873, and that reductions to more definite positions that other showers admit of will perhaps be further illustrated when the unusually large collection of observations in the year 1873-74 have all been projected. The radiant N$_{11}$ (G. & H., 1874, No. 83) appears to have arisen out of a distinct meteor-shower in Cassiopeia (A$_{11}$, G. & H., Nos. 83, 98 in the Supplementary List), accompanying that of the Perseids, reaching a maximum about the 10th and again on the 23rd of August, which has been well marked among the recent observations at a place (provisionally assigned to it) at γ Cassiopeiæ. The relation of this new shower to the two formerly adopted radiant-points A$_9$ and N$_{11}$, and its final separation from the Perseus radiant-point, with which it has probably been identified by indiscriminate projections hitherto, will form an important subject for investigation in future observations.

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[*] Herrick's shower at 99°, +26° (ε Geminorum), Gruber's and Schiaparelli's position from Zezioli's observations, and one in Tupman's list (No. 90) are the only recorded radiant-centres of the October period in the constellation Gemini.

Oct. 17–28, Radiants (Gruber).	Years of Maximum abundance.	Duration of the shower. October.	Date of Maximum frequency. October.	Perc. No. of Meteors on Max. Date.	Position of Radiant-point.		Corresponding Radiant-points in other Lists.			
					R A.	Decl.	Position.		Duration.	Sign or Character, Reference, &c.
							R A.	Decl.		
					°	°	°	°		
I.	1849, 51.	17	17	22	23·8	+26·7	.	.	.	....
II.	1848, 49, 67, 68.	17–24	21	36	92·7	+18·2	90	+15	Oct. 17–Nov 13.	O. (G. 1874, No. 157) *Orionids.*
III.	1848, 49, 67.	17–26	17	15	324	+61·5	340	+58	End of October	Schmidt } (Greg, 1874,
							334	+54	Oct. 16–31	B_{10}, Heis. } No 144.)
IV.	1849, 70.	18	18	23	1·6	+29·9	.			. . . ..
V.	1849, 70.	19	19	23	39	+30·1	46	+27	Oct. 14–Nov	R_3 (G & H, S. & Z., Tupman, Schmidt, *Muscids*, Greg, 1874, No. 129).
							45	+23	Oct 1–15.	R_3, Heis
VI.	1848, 67, 68, 70.	17–25	22	17	58·1	+18·8	55·5	+16	Nov 1–10.	Tupman. 91, } *Taurids*
							55	+18	Nov 1–15.	R_4, Heis, } (Greg, 1874,
							64	+16	Oct 25–Nov 21	RG_2 (G. & H.) } No. 156).
VII.	1848. 49, 67, 70, 72.	20–22	22	20	15·8	+26	.		…	[See also No. I.]
VIII.	1868.	20–21	21	23	75·3	+23·9	74	+25	Oct 18–21, 1867	Tacchini (Greg, 1874, No 157; see No II)
IX.	1868.	22–27		.	109·5	+25·2	111	+29	Oct 23 (A.M.) 1868.	161, S & Z (*Geminids*: Herrick(?) 1839, G 1874. No 142).
							105	+24	Oct 12 (Tupm. 90)	
X.	1848, 49, 67, 70.	23	23	20	34·6	+19·4	33	+21	Oct. 19–27.	Schmidt (Greg. 1874, No. 129, see No V)
XI.	1848, 49, 67, 70.	23	23	19	2·4	+20·6			.. ...	[See also No IV.]
XII.	1849.	24–25	24	21	21·2	+54·7	15?	+57·5?	Sept (?)–Nov (?)	$A_{14, 15}$, G & H. (G 1874, No. 173)
XIII.	1849	22–24	24	15	23·3	+14·7	23	+ 8	Oct 18–Nov 10	RB. (Greg, 1875, No 195).
XIV.	1848, 67, 68, 72.	26–28	26	41	36·6	+38·1	23	+40	Oct 16–31.	P_1, Heis [See also No V.]
XV.	…	22–28	27	16	250	+87	205	+85	Oct 16–31	N_{18}, Heis (G 1874, No 143).
							10	+88	Sept 19–Oct 20	N_{14}, G & H (G. 1874, No. 128).
XVI.	1848. 67, 68.	28	28	23	89·7	+71·0	110	+70	Oct. 28.	163, S. & Z

Supplementary Table and general Radiant-list (continued), showing the corroborations of former meteor-showers and new radiant-points, derived by Mr. Greg from the Radcliffe Observations of 1870–74, the British Association Catalogues in these Reports of 1867–74, and from private sources (R. P. Greg, A. S. Herschel, J. E. Clark, T. W. Backhouse), including about 1000 observations independent of the periodic meteor-streams of Perseids, Orionids, Leonids, Andromedes, Geminids, Lyraids, and of meteors belonging to the annual star-shower of the 1st–3rd of January.—Supplement to the general list of Radiant-points 1874 (volume of these Reports for 1874, p. 324), by R. Greg.

Old Meteor-Showers and Radiants.

B A Cat. No. Greg, 1874.	G. & H. Sign of Radiant.	Dates and Confirmations by Observation.	Position as confirmed.	
			R A.	Decl.
1.	N G	(December, January) confirmed probably for December 4–8 at .	280°	+80°
2	M 1, 2	Confirmed tolerably December 13, at	139	+53
11.	M G 1	December 19 to January 2, partly confirmed	...	..
14.	A G 1	February 27 to March 6, partly confirmed ..	60	+37
16.	G 3	January 9–19, partly confirmed	...	..
26	M 3	February, partly confirmed	165	+35
45.	M Z.	Partially confirmed	...	..
47.	D G 1	Confirmed March and April	..	...
53	S Z 2	(= ? S G 2) in part fairly confirmed. . .	.	..
55	M 6, 7, 8	Fairly confirmed..	...	...
59*a*.	Y	(? M 3 Z) partially confirmed . .	...	...
67.	Q 1, 2	Confirmed April and May, but not so strongly marked as between 1862–1867	230	+29
67.	Q 2	(=Q 1, 2) May and June, confirmed at ..	232	+30
69.	W.	(May and June) partially confirmed at	285	+35
72.	[W & Q G ?]	Slightly confirmed at, not so well marked as formerly (?)	295	+12
74	W G	Partially confirmed at	308	+15
77.	B 1	Fairly confirmed at {300°, +70° 315°, +63°}	307	+67
79.	Q G	Only slightly confirmed; probably more quiescent than some years ago, at	303	+7
81.	B 4	Well confirmed (15th July to August) at ...	315	+45
		Very well confirmed (August)..	310	+45
83.	N 11	Partially confirmed	...	...
98.	A 9	Well confirmed at	360	+45
83. 98.	A 11	Confirmed very fairly, July 25 to August 26,(new radiant, γ Cassiopeiæ, 12°, +59°) at	352 to 10	+62 +60
84.	M G 5	Partially confirmed	...	...
88.	Q 3	Very slightly confirmed only (perhaps a radiant connected with it in Serpens?) at	265	+ 3
90.	..	*August* (July), probably confirmed at	273	+28
93.	N 12, 13	Partially confirmed (August)	...	...
		Fairly confirmed (in August only) at	240	+83
94.	H	Not noticed	...	...
95.	.. ...	Very slightly confirmed (and perhaps connected with 96, 112, or 125, TG, E 1, E 2) at	340	+48

Old Meteor-Showers and Radiants (*continued*).

B.A. Cat. No. Greg, 1874.	G. & H. Sign of Radiant.	Dates and Confirmations by Observation.	Position as confirmed.	
			R.A. °	Decl. °
96.	T G.	(or ? 95) slightly confirmed for August at	340	+35
97.	T 1	Well confirmed (August) at	344	+16
99.	V	Slightly confirmed	.	.
102.	B Z	Confirmed July 10 to September 30 Position for August strongly confirmed at	250 255	+67 +64
103.	R 1, 2	Fairly confirmed (in August) at .. .	361	+32
111.	T 2, 3	Well confirmed (August) at ... Fairly confirmed (September and October) at	359 358	+18 +14
112.	E 1	Tolerably well confirmed (August only) at .	340	+67
113.	B 5	Slightly confirmed (August) at . Not confirmed, September (? = No. 130, B 7–9, Heis).	283 .	+44
115.	R G 1	(August) radiant perhaps extends to . .	64	+22
122.	(Tupman)	(August 6–12). Very well confirmed by the 1870–71 Radcliffe observations . ..	.. 94	... +62
125.	E 2	Slightly confirmed (August only) at	337	+52
129	R 1 ?	(Of Heis). September (not = R 3, October 1–15), well confirmed at 40°, +35° to 33°, +35°	36	+35
130		*August* (September) suspected at	287	+67
131.	. .	Well confirmed at .	70	+67
136.	$F_{1,2}$	Very slightly confirmed	.	
142	....	September, 100° +36°, and October, 98°, +30°, Well confirmed at	100	+33
141. 147.	. ..	Tupman, confirmed ? September, at .	130	+32
144.	.. .	Perhaps confirmed (October) at . . .	325	+60
145. 167.	P 1	(Of Heis) Apparently fairly confirmed in October (but possibly, however, only a *pseudo*-shower) at . . .	20	+40
146.	B G 6	Well confirmed (October 15–31) at .	291	+50
156.	R G 2	Extremely well confirmed (November 6–12) at	56	+24
156.	G 1	Well confirmed (? begins November 5) .		.
157	O	Confirmed well	.	
166	D G 2	Confirmed by Clark, at	290	+65
185. =167.	..	December 5–13 Probably confirmed at ..	30	+28
168.	A 16	(? Not Andromedes) fairly good at . .	50	+49
169.	......	Slightly confirmed November 12 to 14, at .	185	+40
172.	A 17, 18, 19	(Heis). December 8–19, probably confirmed at	20	+60
172.	A 17	(Greg). Confirmed December 4–8 (*Andromedes**) at..	25	+42
173.	A 14, 15	(October). Well confirmed at	5	+55
173.?	A 15	(? 14, 15) Moderately confirmed, November	..	..
174.	A G 1	Partly confirmed December 4–12 at	80	+20
175.	.....	November 4–30, well confirmed (possibly a new radiant) at	127	+47
176.	K G	Slightly confirmed at	160	+60
185. =167.	......	December 5–13. Probably confirmed at ..	30	+28

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* The observation of a star-shower on the night of December 7th, 1830, recorded by the Abbé Raillard ('Comptes Rendus,' vol. viii. Jan.–June, 1839, p. 177), is wrongly described as *a bolide* (?) on the *12th of December* of that year in a former volume of these Reports (for 1873, p. 396); but there can be no doubt that the shower was a regular return of the 'Andromedes' connected with the periodical returns of Biela's comet.

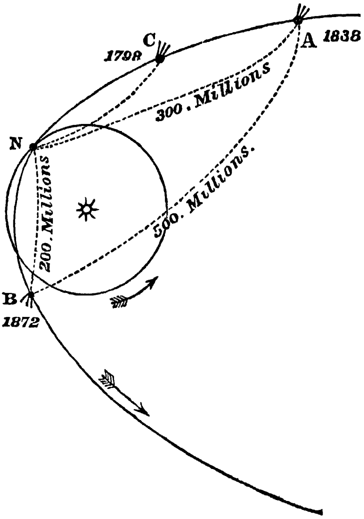
New Meteor-Showers (1875). Principally from the English Observations.

B A. Cat. No continued. Greg, 1875.		Date and Observations.	Position of the Radiant.	
			R.A	Decl.
			°	°
188.	N 5	Observed by Denza, Feb 11–27, 1868, at	105	− 5
189.	..	Omitted in new B A Catalogue, but in 1867 Atlas, March 3–27 Perhaps connected with the next, No. 190	36	+67
190		January 15–February–March 15. Strongly suspected at .	65	+61
191.		April 13–May 1 Probable, extending about from 225°,+22° to 210°,+10°	217	+16
(53 *a*)				
192		March 18–19, 1874 Observed by Mr Backhouse	157	+13
(69 ?)		May 19–June 21. Probably new (?=W, No 69)	263	+37
(110 ?)		July 10–30 Very well pronounced Formerly no doubt confused between W and Q 1 2 Confirmed also by Mr Herschel, July 16, 17, 1870, at 257°,+36°	255	+37
(83, 98)		July 25–August 26 (especially Aug 7–12 and 23). A 11, *Cassiopeids*, accompanying the August shower of Perseids	12	+59
193		September Well pronounced in Tarandus, possibly has been confused with $F_{1,2}$ (No 136)	50	+75
		September Fairly pronounced at	44	+73
(119 ?)		Suspected, September, at	305	+22
194		October 18–23, Gruber, Oct Radiants IV., XI. (average position)	2	+25
195	...	October 18–Nov. 10 (T. W. Backhouse, Oct 30, 1872, at *o* Piscium, 25°,+8°), RB	23	+ 8
196		October 17–24, Gruber, Oct. Radiants I, VII., XIII (average position).	21	+22 5
197.	.	October 28, S & Z. 163	110	+70
		October 28, Gruber, Oct. Radiant XVI	89·7	+71
198		Very fairly pronounced shower, Nov 4–Dec 8, at	34	+ 7
199.	.	J E Clark, Dec. 10–12, 1873 (very accurate radiation).	57	+ 6

Corrections to the last Catalogue (1874).

No 12 (page 325). Tupman's positions 177°,+22° and 205°,+4° should belong respectively to No. 5 and No. 8, S. & Z 14 should change place with S. & Z. 25, No. 18.
No. 69*a* (page 330) should be 68*a*, and should follow No. 68 in the Catalogue.
No. 83=98 in Cassiopeia, confirmed (?=E 1 in part), includes also S. & Z. 105
No. 90, ?=87, not 89.
No. 129. R 3 of Greg and H =Nos. 167 and 185, November and December.
No. 141=147, receives a new confirmation in September, at 130°+32°.

Papers relating to Meteoric Astronomy.—In the Sheffield Scientific School of Yale College, in the United States, Prof. H. A. Newton delivered a lecture on March 9th, 1874, "On the story of Biela's Comet," in which he details with much completeness the circumstances of the positions of Biela's comet in its orbit relative to the earth at the times of the occurrences of the greatest meteor-showers known to have proceeded from the earth's approach to this comet's orbit. The line of the nodes, or the place of the earth's nearest approach to the comet's track, being at N, it appears that in the year 1798, at the time when the earth encountered at that point the great meteor-shower of the 6th of December in that year, observed by Brandes, Biela's comet was in the position marked C, somewhat nearer to the earth than at the next occasion when a similar occurrence was observed in the year 1838. The comet was in the latter year at a point marked A, about 300 millions of miles distant, measured along its orbit, from the earth. At the last great reappearance of this star-shower connected with Biela's comet, on the 27th of November, 1872, the two bodies (which had last been observed in 1852 as forming the nucleus of the comet) must have occupied a place on the elliptic orbit marked B, at about 200 millions of miles along the comet's path from the place of the earth's intersection with the meteor-stream at N. It thus appears that a long extended group of meteor-particles must accompany the comet in its periodical revolution, preceding it to a distance of 300 millions of miles in front, and following it to a length of 200 millions of miles in the rear of its actual position, or occupying, if there is no reason to suppose this elongated meteor-current discontinuous, fully 500 millions of miles in its observed length along the comet's path.



A similar investigation has led Prof. Kirkwood, of the Indiana State University, to a remarkable conclusion regarding the clusters of meteors included in the current of the Leonids of November, that at least one other such cluster besides that connected immediately with the comet exists to mark the ancient disintegrations which this cometary body must have undergone. The following letter in 'Nature' of January 3rd, 1875, relates the results of Prof. Kirkwood's investigation, and describes some observations of his own by which they are supported.

" *The Meteors of November* 14.—The writer some time since called attention to the fact that the dates of certain meteoric showers, given by Humboldt and Quetelet as belonging to the November stream, indicated the existence of two distinct and widely separated clusters moving in orbits very nearly identical. The years thus designated were 1787, 1818, 1820, 1822, 1823, 1841, and 1846. As the last two were subsequent to the great display of 1833, the meteors seen were noticed only in consequence of their being specially looked for; and as the number conformable to the radiant of the Leonids is not given, there may be some doubt whether those observed really belonged to the November stream. The former displays occurred before the periodicity of such phenomena had been suspected, and the number of meteors would seem to have been considerable. As the shower of 1787 preceded by twelve years the great meteoric fall witnessed in South America by Humboldt, the group from which it was derived had passed beyond the orbit of Saturn at the time of the latter display. The phenomena of 1818, 1820, 1822, and 1823 indicate that, as in the case of the major group, which passed its descending node between 1865 and 1870, the meteoroids are extended over a considerable arc of their orbit. From November 1787 to the middle of the nodal passage of 1818–1823 is about 33$\frac{1}{3}$ years—a period nearly the same as that of the principal cluster. These facts alone were regarded by the present writer as giving reasonable probability to the hypothesis of an approximate identity of orbits. In 'Nature,' vol. xi. p. 407, it was shown that the meteor-showers of October 855 and 856 were probably derived from the stream of Leonids*; and it is certainly remarkable that the interval from 855 to 1787 is equal to twenty-eight periods of 33·293 years. Again, the shower observed in China, Sept. 28, A.D. 288, making proper allowance for the nodal motion, corresponds to the same epoch, the interval between 288 and 855 containing seventeen periods of 33·35 years. In view of the fact that the shower from this cluster was due between 1851 and 1855, the following extract from the writer's notebook is not without interest.—

"'Newark, Delaware, Nov. 13, 1852. . . . On the evening of the 11th, from 7 to 10 o'clock, an aurora borealis of ordinary brilliancy was constantly observed. About midnight the sky became overcast with clouds, thus preventing our watch for meteors which we were about to commence. On the 12th, from about 3 to 9 o'clock A.M., rain fell almost incessantly. About noon the clouds broke away, and the night between the 12th and 13th was quite clear. During six hours (from 10 P.M. to 4 A.M.) constant watch was maintained at four windows, facing north, south, east, and west. From 10 to 1 o'clock the observations were conducted by Prof. Ferris and myself with assistants. At 1 the place of Prof. Ferris was taken by Prof. Porter, who remained, with myself and assistants, till 4. We observed—

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* The first of these showers is recorded by an Arabian chronicler, and also as follows in the 'Annales Fuldenses' —"Per totam noctem igniculi instar spiculorum occidentem versus per aerem densissime ferebantur" That of the following year (856) is cited from similar but somewhat less authentic sources in Quetelet's Catalogue, and is suspected to be identical with it. By comparing the dates of these two showers with that of the famous one which took place in 1366 (a year, as well as the year 868, in which the comet accompanying this star-shower was also seen *vide* these Reports for 1873, p. 401), Boguslawski first suspected an advance in the node of the meteor-orbit before its real form and period had yet been detected. But the showers of 855–56 preceded by 12 years the regular periodic shower of 868; and it is remarked by Professor Kirkwood that this divergence of their dates agrees exactly with the interval by which the well-marked November showers of 1820 and 1822 anticipated the appearance of the celebrated star-shower of November 13th, 1833. ('Nature,' *sup. cit.*, March 25th, 1875.)

	h		h		
From	10	to	11	20	meteors.
,,	11	,,	12	35	,,
,,	12	,,	1	40	,,
,,	1	,,	2	52	,,
,,	2	,,	3	75	,,
,,	3	,,	4	59	,,
		Total		281	,,

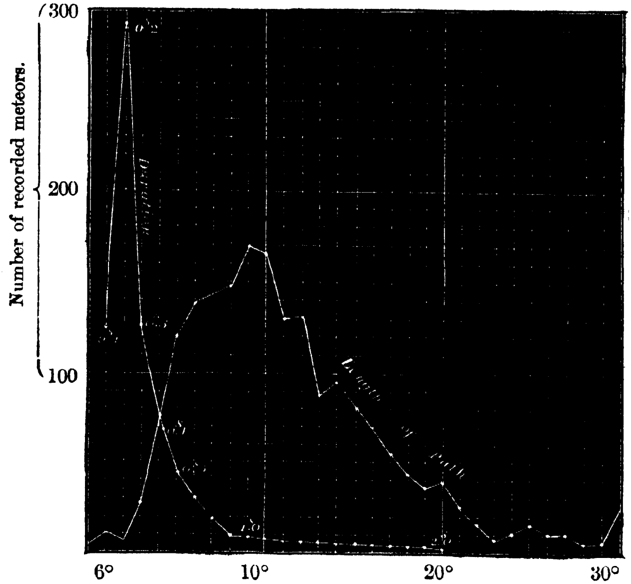
" 'When the meteors were most numerous, near 3 o'clock, the common point of divergence in Leo was distinctly observed.'

" I may here add, although the fact is not stated in my memoranda, that the conformable meteors, or a majority of them, were seen near the radiant, and that they were generally smaller and had shorter tracks than the November meteors observed between 1865 and 1870. The number seen was too small to be called a shower; at the maximum, however, the fall per hour was nearly double that of ordinary nights. In short, I have no doubt that they were Leonids, and think it highly probable that they were derived from a distinct cluster which passed its perihelion in 1787 and 1820. We have therefore nine recorded meteor-falls which indicate the existence of a second cluster of Leonids, viz. those of A.D. 288, 855, 856, 1787, 1818, 1820, 1822, 1823, and 1852. The showers of 855 and 856 may be somewhat doubtful. If derived from the same meteor-cloud as the others, the dates would indicate considerable perturbations either by Uranus or the earth. The displays have been much less conspicuous than those of the major group, and hence the phenomena have been less frequently observed. The period is about 33·33 years, while that of the other swarm, according to Newton, is 33·25 years. Since their separation, therefore, the latter has gained nearly two-thirds of a revolution in their relative motion. The estimates which have been made in regard to the recent entrance of the cluster into the planetary system must consequently be rejected.—DANIEL KIRKWOOD."

" Bloomington, Indiana, U. S. A ,
April 20th, 1875."

Lists of Meteor and Meteor-shower observations and of Cometary Radiant-points.—In the above-quoted publication (of May 1874) of the Italian Spectroscopic Society, Prof. Schiaparelli reviews at some length the catalogue of observations and of meteor radiant-points by Capt. Tupman, deriving from them chiefly average results relating to the apparent length and to the time of flight of the recorded meteor-tracks. The annexed diagram shows approximately the numbers of meteors in the list of different lengths and durations of flight proceeding by intervals of 1° up to 30° in length of path, and of one tenth of a second up to two seconds in the time of flight. The curve of relative frequency in length of path is drawn from the actual numbers of the observations, including 1951 recorded tracks; and the most frequent lengths of path recorded among them are between 7° and 10°; the average length of path derived from the whole series of observations in the list is $11^{\circ}\cdot0$, falling a little short of the mean apparent length of course of meteor-tracks ($13^{\circ}\cdot9$) assigned by Coulvier Gravier.

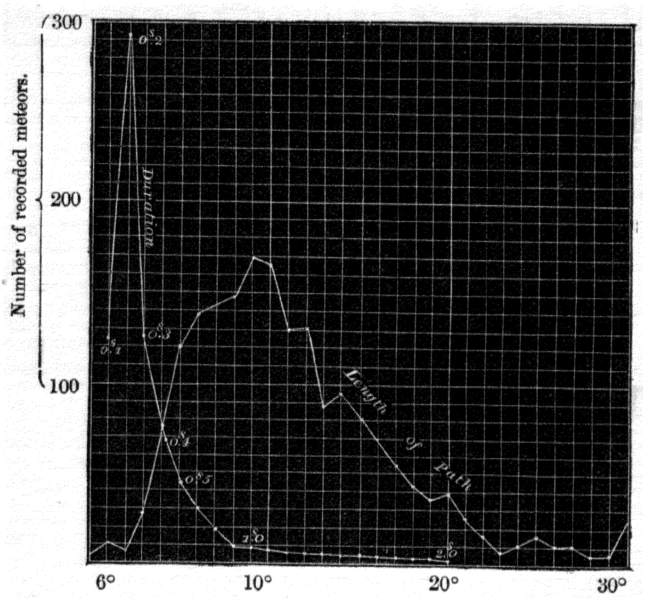
The curve of frequency of the different times of flight is a reduced one from the total number of 1613 observations, allowing for the rough estimations at $0^{s}\cdot5$, $1^{s}\cdot0$, $1^{s}\cdot5$, and $2^{s}\cdot0$ preponderating greatly among the other more accurate determinations, and diminishing the scale of modified numbers so obtained to one half of the original figures, in order to bring the crest of the curve within the limits of the diagram. A duration of $0^{s}{\cdot}2$ is far the most common time of flight assigned to about one third of all the observations; but a tendency to record longer times of flight in the later years (1870–71) of the Catalogue than in the first year (1869), in which many durations of only $0^{s}{\cdot}1$ were recorded, indicates that these exceedingly momentary times of flight may very probably have been a little underrated. Above 1·5 second there are actually noted in the list meteors of great durations in the following numbers:—



Duration of flight in seconds	1·6.	1·7.	2·0.	2·5.	3·0.	Above 3 seconds.
Numbers of meteors recorded	1	2	25	9	11	11

total 59, or only $3\frac{2}{3}$ per cent. of all the appearances recorded. Only 47 meteors with times of flight varying from $1^{s}{\cdot}1$ to $1^{s}{\cdot}5$ (or 2·9 per cent. of the whole) are noted in the list, the remaining 1506 meteors all having durations not exceeding one second. The longest time of flight observed was 16 seconds, and the average duration of all the recorded times of flight was $0^{s}{\cdot}44$. If durations exceeding 1 second are excluded as anomalous and exceptional from the general result, the average time of flight of the remaining 1506 meteors was $0^{s}{\cdot}32$.

The following agreements of radiant-points in Capt. Tupman's list with showers apparently corresponding to them obtained from Zezioli's observations are pointed out by Schiaparelli. The sign and number of the shower in Mr. Greg's last general list to which they correspond is added for reference to that Table; and although these separate correspondences exhibit very excellent agreements, they afford little confirmation of the distinctness accurate determinations, and diminishing the scale of modified numbers so obtained to one half of the original figures, in order to bring the crest of the curve within the limits of the diagram. A duration of $0^{\mathrm{s}}{\cdot}2$ is far the most common time of flight assigned to about one third of all the observations; but a tendency to record longer times of flight in the later years (1870–71) of the Catalogue than in the first year (1869), in which many durations of only $0^{\mathrm{s}}{\cdot}1$ were recorded, indicates that these exceedingly momentary times of flight may very probably have been a little underrated. Above 1·5 second there are actually noted in the list meteors of great durations in the following numbers:—



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Radiant-point in List of Schiaparelli and Zezioli (S. & Z.).				Radiant-point in Tupman's List (T).				Radiant-point or Group in Greg's General List, 1874.	
Ref. No. S. & Z.	Duration of Shower.	Position of Radiant.		Ref. No. T.	Duration of Shower.	Position of Radiant		Ref. No G., 1874.	Particular Radiant-points and Remarks.
		R.A.	Decl.			R.A.	Decl.		
5	Jan 11–12	183°	+28°	4	Jan. 4–31	180°	+35°	11	MG (G & H.), Jan. 1–25; 183°+36°. A well-defined radiant-group, centre at T 4, apparent connexion with comet 1792 (II) not confirmed.
25*	Feb. 1.	215	+30	9†	Feb. 3–10	210	+36	(†) 12 and (*) 18	Shower properly belongs to 12, a group contiguous to 18 (Q Z). No cometary radiant-point confirmed.
147*	Sept. 8.	60	+32	64†	Sept. 7–15	66	+40	(†) 114	FG. (G & H), including also T 74, August shower in Auriga.
								(*) 129	R_3 (G & H.) Muscids Radiant group and its duration uncertain.
189	Dec 27	137	+45	102	Dec. 23–27	130	+49	2	$M_{1,2}$ (G & H) Approximate agreement with comet of 1680 not confirmed

As instances of close apparent connexion of meteor-showers with comets which either have been or which yet remain to be verified by repeated observations, attention may be drawn to the comparative list of meteor-shower and cometary radiant-points in the Table at p. 350 of the volume for 1874 of these Reports, in which examples of correspondence in the principal characters of nodal or shower-dates and positions of the radiant-centres will be found to be very numerous, and to be chiefly exemplified in the annexed selected list of the most important cases (p. 229).

The last Annual Report of the Council of the Royal Astronomical Society ('Monthly Notices,' vol. xxxv. p. 243) contained some brief remarks on these coincidences. It is pointed out that the earth's nearest approach to a comet's orbit is sometimes (if the inclination of the comet's orbit is small) at a considerable distance from the node, and in certain cases, as that of Lexell's comet (1770 I), Clausen's comet (1743 I), the comets of 1833, 1702 II, 568 II, the best agreements with known meteor-showers are found at the dates of the earth's nearest appulse to their orbits rather than at those of its nodal conjunctions with them. Another example of the same kind appears to be that of Halley's comet, 1835 III, with a date of appulse May 4th, about twelve days earlier than that of conjunction with the node, and with a radiant-point at that place which does not differ greatly from that of a considerable star-shower observed by Captain Tupman on the 2nd and 3rd of May, 1870, and on the 29th of April, 1871. In the place of the usual sign for the node, a capital Greek Omega (erect or inverted) might be used to signify an "appulse," or point of closest approach (which is generally near to one of the nodes) of a comet's orbit to the earth's. In a later Table of this Report this sign is, for

Comet and its node or Appulse.	Date of Earth's Approach or Appulse (1875).	Cometary Radiant-point (1875) R.A.	Cometary Radiant-point (1875) Decl.	Most accordant Meteor-showers. Radiant-point R A	Radiant-point Decl.	Date or Duration.	Sign or Ref. No
1792 II ☋ ..	Jan. 5.	194°	+24°5	183°	+28°	Jan 11–12	S & Z 5
1797 ☋	Feb 18.	211	+ 9	205	+ 4	Feb 13	T 8
1864 V ☋ ...	Mar. 1.	251	−13	247	− 3	Mar 3–25	(G & H) SZ_1
1862 IV ☋ .	Mar. 16	249	+ 1	243·5	+ 4	Mar. 7	T 27
1556 ☊ ...	Mar 19.	179	−26	174	−30	March.	Δ_4
1264 ☊	Mar 25.	182	−28				
1683 ☊ .	Mar 16.	207	−48	192	−38	March	H_1
178 ☊	Apr 23.	203	−32	194	−30	April	H_2
1861 I ☋ .	Apr 20.	270	+32	277·5	+31·5	Apr 19–21	QH_2 (*Lyr*)
1839 I ☊	Apr 15	116	−36	126	−42	April	Γ_4
1748 II ☋	Apr 22	255	+27	260	+24	April 25	S & Z 63
1853 II ☋	May 1.	296	+13	291·5	+ 8·5	May 2.	T 34, 35
1618 III ☋ .	June 10.	273	± 0	274 269	− 7·5 −11	June (avge) June	Schm. O_1
837 I ☊ .	May 1	334	−16				
1835 III near the ☊ .	May 4	337	± 0	326	− 2·5	Apr. 29 to May 3	T 33
1781 I ☊ .	June 14	338	+57	333	+42	June	B_2 (Heis)
1850 I ☋	June 24.	312	+61	315	+60	June 11 to July 11	B_1, (G & H)
				315	+54	July 1–15.	B_3 (Heis)
1864 II ☋ .	June 27	12	+ 6	7 18	+ 4 + 0	July.	Schm
1770 I near the ☋ ...	July 8.	276	−21	285	−13	June 28 to July 6	T 36
1770 I ☋ ...	Aug. 6.	283	−20	285	−25	July 18 to Aug, 31	Schm
568 II ☊ ...	Aug. 5.	259	−36	250	−35	August	A_5(H.&N.)
				266	−42	August	Schm.
1764 ☋	July 25.	49	+46	44	+56	Aug 9–11.	A_{10} (Perseids)
1862 III ☋	Aug 10.	43	+57·5				
1870 I ☋	Aug 12	43	+53				
770 ☋ .. .	July 8.	39	+45				

Most accordant Meteor-showers. Sign or Ref. No	Date or Duration.	Radiant-point. R A.	Radiant-point. Decl.	Cometary Radiant-point (1875). R.A.	Cometary Radiant-point (1875). Decl.	Date of Earth's Approach or Appulse (1875.)	Comet and its node or Appulse.
Schm.	August.	55°	−18°	41° 49	−13° − 9	Aug. 10. Aug. 27.	1852 II ☊ 1596 ☊
Schm. T 65	August. Aug 20–25	53	+1	47	− 6	Aug. 31.	1845 III ☊
S & Z 140	August 10	47	+18	47·5 41	+13 +11·5	Aug. 19. Aug. 9.	1862 II ☊ Do. near the ☊
(G & H) $R_{1,2}$	July 28 to Sept 3	8±	+36	3·5	+38·5	Aug. 14.	1780 II ☋
T 67	August 31.	85	−15	92	± 0	Aug. 23.	1797 ☊
Schm.	Sept.	54	−12	53 49	−16 −15·5	Sept 10. Sept. 13.	1854 IV ☊ 961 ☊
Schm	Sept.	142	+67	145 172	+50 +68	Sept. 19 Sept 30.	1683 ☋ 1840 III ☋
Schm	Sept. 3–10	17	+ 9	18	+18	Sept 19.	1769 ☋
(G & H) $T_{2,3}$	Aug. 22 to Oct 15	& 21 359	+18 +17	24	+18	Sept. 28.	Do. near the ☋
Heis A_{15}	Oct 1–15	57	+61	54	+52	Oct. 4.	1847 VI ☋
Schm	October	40	−30	39	−30	Oct. 19.	1779 ☊
(G & H) $F_{1,2}$	Sept 17 to Nov. 24	82	+50	81 78	+57 +60	Oct. 21. Oct. 24.	1842 II ☋ 1848 I ☋
(G&H) LG	Oct 3–20	142	+44	157	+39	Oct. 22.	1739 ☋
T 97	Nov. 7.	160	+40				
L (*Leon*)	Nov. 13–15	149	+23	150·5	+23·5	Nov. 13.	1866 I ☋
(G&H) A_{16} (*Biela*)	Nov. 27.	25	+43	25·2	+42	Nov. 27.	Biela ☊ 1866–72
Schm	December	4	− 4	7	− 2	Decemb.	1743 I ☊ and near the ☊
(G&H) $M_{1,2}$	Jan 1 to Feb 9.	135	+40	135 to 144	+25 to +24	Jan. 27 to Feb. 12.	1833 ☋ and near the ☋
S & Z 32	Feb 13.	133	+26				

brevity, introduced; but it is not thought necessary to use it in the above selected Table of cometary coincidences, where, for greater clearness of description, such points of close approach (or of "appulse" of comet-orbits to the earth's) are simply denoted in the first columns of this Table as being "near" the comet's ascending or descending node. For the general purposes of comparison between the probable orbits of observed meteor-streams whose dates and radiant-positions may be hereafter or have already been sufficiently well determined, and those of certain comets whose computed orbits are found to pass, at the points of approach to the earth's orbit, either very near to or at no very remote distance from it, and for convenience of reference in identifying such examples of supposed agreement between meteor-showers and cometary radiant-points as have already been pointed out, the dates and positions of the radiant-points of all the computed comet-orbits intersecting the ecliptic plane within a quarter of the sun's distance inside or outside of the earth's orbit are collected together in two Tables (pp. 232, 234) in the order of dates and of position of the cometary radiant-points above or below the equator, the two lists being arranged for the northern and southern hemispheres respectively, according to the north or south declinations of the computed radiant-points. As these radiant-points were computed by the approximate graphical method devised by Schiaparelli (Entwurf einer astronomischen Theorie der Sternschnuppen, p. 78, § 49), the tests which the elaborate calculations of many of the radiant-points by Dr. Weiss supply are employed to check the graphical constructions; and all the radiant-points originally calculated by Professor Weiss, who takes into account what has elsewhere been omitted throughout in the graphical preparation of these Tables (the ellipticity of the orbits of those comets which are known to be periodic, and whose orbits accordingly differ sensibly from parabolas), are included as standards of correct determinations in the present lists.

In the column of reference numbers at the beginning of the Table the names of discoverers and particulars of meteoric connexion of some periodic comets are added, together with references to other numbers where comets are known or conjectured to be more or less probably identifiable with comets of an older date, although no elliptic figure may have been observed or calculated in the dimensions of their orbits. A question sign is added after that of the node or appulse if the elements are uncertain, and the date in the following column is corrected for precessional alteration to the year 1875 from that of the comet's apparition. The fourth column contains the comet's radius vector or distance from the sun in terms of the semidiameter of the earth's orbit as unit, at the node or point of intersection of the orbit with the ecliptic, unless the appulse replaces the node in the Table, when the comet's distance above (+) or below (—) the earth's orbit *at the point where its radius vector is unity* is substituted in brackets (in terms of the same unit as the scale of measurement) for the value of the radius vector. A similar estimate to that afforded by the radius vector in other cases can thus be formed of the degree of proximity in which the path of the comet and the earth's orbit approach each other in such instances at their points of close conjunctions at equal distances from the sun. Thus the comet 1862 II crossed the ecliptic plane (with retrograde motion, at an ascending node corresponding to the shower-date on Aug. 19th) about 0·03 (or twelve moon's distances) without the earth's orbit; but, owing to its small inclination, in approaching nearer to the sun it slightly neared the earth's orbit; and at a point corresponding in the earth's annual motion to about the 7th of August, it passed only 0·025 earth's solar distance (or about ten times the moon's distance) above the earth's orbit. Thus the observation of a star-shower not far from the latter date, between the 7th and 19th of August (or on August 10th, S. & Z. 140, in the above comparative list), with a radiant-point corresponding closely to that of meteor *poursuivants* of the comet at this point, is in satisfactory correspondence with the earth's conjunction with this comet's orbit, although the date of the shower and of the nearest conjunction of the orbits is not exactly that of the earth's passage across the line of the comet's nodes. In several other cases (as in that of Lexell's comet) of comets moving nearly in the ecliptic, the point of nearest conjunction and the time of the year when the earth passes through it are very far removed from the place and from the corresponding time of the earth's passage through the node; and the approach of the two orbits is yet often closer at the former than at the latter place.

The particulars of each comet's approach to the earth, whether occurring at the node or appulse, will be found, as thus described, in the columns of the accompanying lists, the dates in column 3 and the places of the radiant-points in columns 5 and 6 being brought up (for precession) to the year 1875, neglecting any perturbations which the orbit of the comet since the time of its appearance may have undergone. In cases of appulses (or of earth's conjunction with the comet-orbits at a common radial distance from the sun), the motions of the meteor-particles are supposed to be equal and parallel to that of the comet in its orbit there, or at the point where its radius vector is equal to the earth's distance from the sun; as no regard is paid in the graphical construction to the slightly elliptic form, both of the orbits of certain comets and of the earth's orbit, which are severally assumed to be parabolic and circular, small errors on these accounts will present themselves in the lists, which, for preliminary purposes, may be looked upon as unimportant.

A + or − sign following the dates indicates if the comet's motion is direct or retrograde; and if the comet was approaching the sun, or if it was very near to its perihelion at the node or appulse, there is added after the radius vector, or appulse-distance, in column 4, a notation sign (* or §) denoting these conditions; where no such sign is added, the comet's motion is receding from the sun. The italic letters after the comets' years in column 2 are intended to supply some information of their general characters and appearance. Thus *d* implies just discernible by the naked eye, d plainly, and *D* brightly so; and D a comet visible by day. *t* t *T* T indicate corresponding proportions in the apparent dimensions of the tails: *t* less than 5°; t, 5° to 15°; *T*, 15° to 30°; and T upwards of 30° in length. Durations of the comets' periods, where elliptic orbits are known to belong or have been calculated and assigned to them, are also roughly indicated by letters corresponding to their lengths of period thus: *l*, periods less than 15 years; l, 15 to 50 years; *L* 50 to 400 years; and L comets of very long periods exceeding 400 years. The letter *p* is added to comets having decidedly parabolic orbits, and *h* to those whose orbits are computed to have been hyperbolic. The sign || following these characters indicates that at its appearance the comet passed very near the earth. The initials P., H. affixed to the comet of 1490 (N. 2) are those of two independent computers, Peirce and Hind, of two distinct and apparently equally probable orbits of the comet; while the mean of two independent sets of orbit-elements assigned to it by Pingré is adopted in the Table for the comet of 1582 (N. 83), to whose designation a similar initial $\frac{P}{2}$ is affixed. The orbit-elements used in the rest of the Table are those of Hind's work 'The Comets,'

List of Radiant-points of Comets in the Northern Hemisphere (N.).

By A. S. HERSCHEL.

1.	2	3.	4.	5.	6.	7.
Reference No. N.	Comet and its Node ☊ ☋, or nearest appulse Ω ℧.	Cometary-Shower date, 1875.	Comet's Radius vect. or least dist. from ⊕ (above +, below −)	Position of Radiant-point 1875. R A	 N Decl.	Meteor-speed. Miles per sec
				°	°	
1	1792 II ☋ *t*	Jan. 4−	1·050	214·5	+16	40·5
	Do (Weiss)	,, 5−	1·07	194	+25	40·2
(5, 7) 2	1490 ☋ d (P)	Dec 25−	0·79	214	+34	35·5
	1490 ☋ *t* (H)	Jan 14+	0·902*	179	+69	22·7
(16, 17) 3	1746 ? ℧ ‖	,, 16+	(+0·07*)	60	+40	12·0
4	1672 ☋ *t*	,, 20+	1·042	256	+20	31·5
(2, 7) 5	1863 V ☋ d *t*	,, 24+	1·09	272·5	+25·5	26·2
(9, 51, 55) 6	1833 ℧	,, 27+	(+0·036*)	135	+25	20·4
7	1810 ☋	,, 29+	1·33	277	+21	26·2
8	1857 I ☋ *p*	Feb. 1+	1·015	261·5	+22·5	32·0
	Do (Weiss)	,, 2+	1·03	261	+23	31·4
(6, 51, 55) 9	1833 ☋	,, 12+	0·787*	144·5	+24	18·5
(15) 10	1854 V ☋ d	,, 13+	0·988	304·5	+35	20·0
	Do IV(Weiss)	,, 13+	0·985	304·0	+37·3	19·0
(12, 13) 11	1858 IV ☋	,, 13−	0·958	272	+10·5	34·0
	Do (Weiss)	,, 13−	0·95	272	+12	33·6
(11, 13) 12	1699 I ☋	,, 14−	1·117	266	+ 9	36·3
(11, 12) 13	1799 II ☋ d *t*	,, 15−	0·72	264	+17	34·9
14	1797 ☋ *d*	,, 18−	1·27*	211	+ 9·5	38·0
(10) 15	1845 I ☋	,, 25+	1·23	309·5	+27	22·6
(3, 17) 16	1746? ☋ ‖	,, 25+	0·97	33	+33·5	11·0
	1746? ℧ ‖	Mar 8+	(−0·008)	30	+28·5	11·7
(3, 16) 17	1231 ℧ d	,, 10+	(+0·058)	32	+31	11·7
18	1862 IV ☋	,, 16−	0·982*	250·5	+ 0·5	41·0
	Do (Weiss)	,, 16−	0·987	249·5	+ 1·0	40·4
(S. 44) 19	1763 ☋ L	,, 18+	1·02	312	+20·5	28·8
	Do (Weiss)	,, 18+	1·02	312·5	+21·5	28·0
20	961 ☋ d	,, 23−	1·27	308	+12	34·0
21	1743 II ? ☋ d	,, 26−	0·703	296	+ 1·5	40·3
(30, 90) 22	1702 II ? ☊ d	,, 29+	0·792	36·5	+ 5·5	14·3
(24, 32) 23	1857 V ☋ *d t*	Apr 4−	0·722	302	+11	38·6
(23, 32) 24	1825 I ☋ *dt*	,, 9−	1·38	312	+12	38·0
25	1847 I ☋ D *t* L	,, 11+	0·052*	231·5	+27	23·4
(S. 47) 26	1580 ? ☋ *D*	,, 12+	1·22	337·5	+31	27·7
27	1808 III ? ☋	,, 15−	0·73	307	+ 4	41·5
(Lyraids) 28	1861 I ☋ d *t L*	,, 20+	1·006*	270·5	+32	29·2
29	1844 II ☋ *d* L	,, 21−	0·92*	288·5	+ 5	40·6
(22, 90) 30	1702 II ? Ω d ‖	,, 22+	(+0·022*)	43·5	+11·5	17·5
31	1748 II ? ☋	,, 23+	0·887*	255·5	+27·5	27·0
(23, 24) 32	1790 III ☋ d *t*	,, 24−	1·060	320·5	+18·5	37·2
	Do. (Weiss)	,, 24−	0·94	319	+19	36·5
33	1784 II ?? ☋	,, 26+	1·056	334·5	+33	31·4
34	1853 II ☋ d *t*	May 1−	0·927*	296·5	+13·5	35·8
35	1835 III ℧ *L*	,, 4−	(−0·031)	337	± 0	41·2
Halley's	1835 III ☋ *DT*	,, 16−	0·872	343·5	+ 2	42·2
Do. 36	1456 ☋ *D* T	,, 14−	0·90	343	+ 2	42·4
37	1757 ☊ *t*	April 26+	0·73	37	+ 2	19·8
	1757 Ω	May 16+	(+0·073)	56	+ 5	19·8
38	1618 III ☋ *DT*	June 10+	1·10*	273·5	+ 0·5	24·2
39	1781 I ☋ d *t* ‖	,, 14+	0·810	338	+57	30·3
(43, 59) 40	1864 II ℧ L	,, 20−	(−0·003)	8	+ 5	44·1

List of Radiant-points (*continued*).

1.	2.	3.	4.	5.	6.	7.
41	1850 I ☋ d*t* L	June 23+	1 082§	313°5	+60°5	26 3
	Do (Weiss)	„ 24+	1 065	312·4	+60·6	25 1
42	1822 IV ☋ d*t*L	„ 25−	1 145§	348·5	+28	42·6
(40, 59) 43	1864 II ☋ L	„ 27−	0·967	13 5	+ 6 5	44·1
	Do (Weiss)	„ 27−	0 953	12·0	+ 6 3	43 15
44	1822 III ☋	„ 30−	1 11*	342	+14	42 6
45	770 ☋ *D T*	July 8−	1 20	39	+45	37·0
46	1770 II ☋ *t*	„ 13−	0 91*	349	+12	40 8
(58) 47	1819 III ☋ *l*	„ 16+	0 790	188	+32 5	11 5
Winnecke's	1858 II ☋ *l*	„ 16+	0 787	188	+30 5	11 6
[Burkhardt's	1766 II ☋ d *t l*	June 7+	0 40§	174 5	+30	10 8] ?
48	1764 ☋ d *t*	July 25−	0 892	49	+45 5	38 4
49	1737 II ☋	„ 30+	0 987	180	+68 5	18 1
	Do (Weiss)	„ 29+	0·975	175	+71	17 85
(Perseids) 50	1862 III ☋ *d* t	Aug. 10−	1 020	43	+57 5	38 0
	Do Hind (1872) ?	„ 9 5−	… ..	51	+52	
„	1870 I ☋	„ 12−	1·012*	43 5	+53	39 0
(6, 9, 55) 51	1833 Ω	„ 12+	(−0 009)	141	+ 9 5	20 4
52	1853 III ☋ D t	„ 13+	0 31	300	+80	27 4
	Do (Weiss)	„ 12+	0 31	299	+80	
53	1780 II ☋	„ 14−	0 817*	3 5	+38 5	35 5
[57] 54	1808 II ☊	„ 16−	1 07	89	+ 6	37·7
(6, 9, 51) 55	1833 ☊	„ 16+	1 10	139 5	+10	21 0
56	1862 II ☊ *d t*	„ 19−	1 037*	48	+14	44 0
	Do (Weiss)	„ 19−	1 027	47 5	+13	43·2
	Do Ω	„ 7−	(−0 025*)	41	+11 5	44 3
(14) 57	1797 ☊ *d*	„ 23−	0 914	92 5	± 0	38 1
(47) 58	1869 I ☋ *l*	„ 25+	(−0 106)	179·5	+21	15·5
Winnecke's	1819 III ☋ *l*	„ 26+	(−0 12)	180	+21	15 5
(40, 43) 59	1864 II ☋ L	Sept 2−	(+0 030*)	57	+ 1	44 1
Donati's 60	1858 VI ☋ *D* T L	„ 8−	0 71	100	+59	37 7
61	B C 68 ? ☋ d t	Sept 18 to Oct 19 + ?	0 855	198	+58	27 0?
(66) 62	1769 ☋ *D* T L	Sept 19+	1 78*	17 5	+18	29 4
(S. 13) 63	1683 ☋ d *t L*	„ 19−	1 175	145	+49 5	33·7
64	1790 I ? ☋	„ 20−	1 068	111 5	+38	41 6
	Do (Weiss)	„ 16−	1 053	108 1	+37 7	40·9
(S 16, 17) 65	1556 ☋ *D T*	„ 22+	0 873	188	+30	20·0
65	1264 ☋ *D* T	„ 26+	0 775	190	+29	20·8
(62) 66	1769 ☋ *D* T	„ 28+	(−0·020*)	24 5	+17 5	27·3
(80) 67	1840 III ☋ d *t*	„ 30+	0 850	172 5	+68	29·7
68	1847 VI ☋	Oct. 4−	0 745*	54	+52 5	35 4
69	1825 II ☋	„ 7+	0·885§	134	+77	32 0
(37) [66] 70	1757 ☋ *t*	„ 8+	(+0·080*)	19 5	+19	22 7
	1757 ☋ *t*	„ 29+	0 67*	30	+26	19·6
71	1857 IV ☋ *L*	„ 14+	0 743§	278	+53	16 3
72	1864 IV ☋	„ 16+	1·05	212 5	+41	22·7
	Do. (Weiss)	„ 16+	1·044	209 6	+42·7	21·9
73	1850 II ☋	„ 19+	0 78*	2 0	+54	20·4
74	1842 II ☋	„ 21−	0 863*	81	+57	35·0
75	1739 ☋	„ 22−	1·08	157	+39	39·1
76	1848 I ☋	„ 25−	0·770*	78	+60	33·5
77	240 ? ☋ d *T*	„ 25+	0 87	200	+25	24 4
(S. 21) 78	178 ☋ d	„ 27+	0 817	212	+ 9	18·9
79	1849 I ☋ L (?)	„ 29+	1·018*	165	+75	31·0
	Do (Weiss)	„ 29+	1 027	185	+61	30·6
(67) 80	1097 ☋ d T	Nov. 1+	0 94	205	+48	28·3
81	1695 ? ? ☋ d t	„ 1+	0 882*	318	+53	13 9
(S. 22) 82	837 I ? ☋ d T	„ 4−	1·34*	104·5	+27	40·7
83	1582$\left(\frac{P}{2}\right)$? ☋ d *t*	„ 9−	1·00*	89·5	+36·5	35·0?
84	1821 ☊ *d t*	„ 11−	1·030*	86	+19·5	32·0

List of Radiant-points (*continued*).

1.	2.	3	4	5.	6.	7.
(Leonids) 85	1866 I ☋ l	Nov. 13−	0·984	150°·5	+23°·5	44·0
(S 55) 86	1743 I ? Ω *l*	„ 13+	(−0·025*)	21	+ 4	13·0
87	1813 I ☊	„ 24−	0·70*	147	± 0	43·7
Biela's 88	1852 III ☋ *l*	„ 27+	0·995*	24·5	+40	14·0
	Do. (Weiss)	„ 28+	.....	23·4	+43	9·7
	Do (1866), Hind		....	25·25	+42	
89	1766 I ☋	„ 28−	0·852	190	+16·5	40·0
(23, 30) 90	1702 II ? ℧ d	„ 29+	(−0·070*)	56	+18	17·4
91	1798 II ? ☋	Dec 2−	0·86*	162	+34·5	41·2
92	1818 I ? ☋	„ 3+	0·798*	359	+53	13·6
Pons' 93	1812 ☋ d *t L*	„ 6+	0·77	200	+68·5	37·0
94	1846 VII ☋ *dtL*	„ 12 (to 17) −	1·087	200·5	+ 4·5	41·0
Méchain's 95	1790 II ☋	„ 20+	1·110*	220	+76	23·3
(? =)Tuttle's	1858 I ☋ *L*	„ 20+	1·075*	221	+77	22·8
96	1680 ☋ *D* T L	„ 27+	0·940*	133	+22	31·5
	Do. (Weiss)	„ 26+	0·95	132	+21·4	31·2
(S. 11 *a*) 43 *a*	1826 III ? Ω	June 28−	(+0·063)	42	+14	37·5

List of Radiant-points of Comets in the Southern Hemisphere (*S.*). *By* A. S. HERSCHEL.

1. Reference No. S.	2. Comet and its Node ☊ ☋, or nearest appulse Ω ℧	3. Cometary-Shower date, 1875.	4. Comet's Radius vect or least dist from ⊕ (above +, below −)	5. Position of Radiant-point, 1875	6	7 Meteor-speed Miles per sec
				R A.	N Decl	
1	1860 IV ☊	Jan 6−	0·955	187°	−22°	43·3
(7, 54, 55) Blainpain's 2	1819 IV ℧ *l*	„ 7+	(+0·08)	343	−30	12·5
3	1299 ?? ☊	„ 15−	0·85*	157	−18	33·3
4	1840 I ☊ *d*	„ 19+	0·955*	127	−27·5	24·2
	Do. (Weiss)	„ 20+	0·964	128·5	−28·5	23·6
5	1718 ☊	„ 29−	1·030§	208	−31·5	40·5
	Do. (Weiss)	„ 29−	1·042	208·4	−31·2	42·8
6	1092 ☊	Feb 5+	0·995*	102	−32·5	15·9
	Do (Weiss)	„ 5+	1·012	103	−34·5	14·6
(2, 54, 55) 7	1743 I ? Ω *l*	„ 6+	(+0·02)	14·5	− 0·5	11·3
8	1506 ☊	„ 6−	1·43	266·5	−37	37·2
9	1861 III ☊	„ 13−	0·890	235·5	−45	41·4
(40) 10	1596 ☋ d	„ 23−	2·4	285	− 8	40·0
	1845 III ☋ d*tL*	„ 26−	1·06	283	− 4·5	37·7
11	1864 V ☋	Mar. 1−	1·115§	250·5	−12·5	44·0
12	1590 ☊ d t	„ 8−	0·702	275·5	−38	12·4
(N. 63) 13	1683 ☊ d *t L*	„ 16−	1·050*	209	−50	33·7
	Do. (Weiss)	„ 16−	1·026	207	−48·5	32·9
14	565 II ? ☋ dt	„ 17−	1·22*	227	−48	37·4
15	1804 ☊	„ 18+	1·138	35	−69·5	23·0
(N. (17 ?) 16	1556 ☊ *D T*	„ 19+	1·20	179	−26	22·6
65) (16 ?) 17	1264 ☊ *D* T	„ 25+	0·98*	182·5	−28	22·7

List of Radiant-points (*continued*).

1.	2.	3.	4.	5.	6.	7
18	1742 I ☊ d t	Mar 28−	0·827	306°	−59°·5	37·3
(23) 19	1737 I Ω	Apr 12+	(−0·13*)	215	−28	37·7
20	1830 I ☊ d t	„ 15+	0·925§	116·5	−36	12·9
(N 78) 21	178 ☊ d	„ 23+	1·22*	203	−32·5	18·8
(N. 82) 22	837 I ☊? d T	May 1−	1·03	334·5	−16	42·5
(19) 23	1737 I ☊	„ 8+	0·52*	235	−15·5	21·7
[26] 24	1006 ☋ ? *D* t	„ 10−	1·12*	345	− 0·5	41·4
25	1748 I ☊ *d t*	„ 13−	0·860*	351	−64	33·4
[24] 26	B.C. 136 ☊ d	„ 29−	1·02	350	−18	44·0
27	1863 III ☊	„ 31+	0·804*	320	−69	31·3
28	1863 II ☊	June 2−	1·068§	2·5	−44·5	37·2
	Do (Weiss)	„ 2−	1·054	0·5	−44·7	36·5
29	1684 ☊	„ 22+	1·022	65	−46	25·5
	Do (Weiss)	„ 22+	1·010	62·7	−47·1	24·6
30	1861 II ☊ *D* T	„ 30+	0·88	52	−37	31·5
	Do. (Weiss)	„ 30,5+	0·864	54	−39	30·3
Lexell's (35,43,53) 31	1770 I ☋ d *t l* ‖	July 8+	(+0·02*)	276	−21·5	16·9
(34) 32	568 II Ω *D* T	„ 23+	(−0·014*)	262·5	−33	12·3
33	1802 ☊	Aug 3+	1·128*	49·5	−63	23·0
(32) 34	568 II ☊ *D* T	„ 5+	0·94*	259	−36	11·5
Lexell's (31,43,53) 35	1770 I ☋ d *t l*	„ 6+	0·782*	283	−20	13·3
[37, 40] 36	1852 II ☊	„ 9−	1·002*	42	−13·5	40·4
	Do (Weiss)	„ 10−	1·013	40·7	−13·5	39·25
[36, 40]·37	1827 II ☊	„ 11−	0·838*	48	− 8	41·4
38	1499 ☊ d ‖	„ 24+	1·035*	319	−64·5	14·4
(41, 45) 39	1558 ☊	„ (25 to) 29−	0·577§	70	−21	36·3
	Do (Weiss)	„ 26−	0·89	65	−22	
(10, 36?, 37?) 40	1596 ☊ *d*	„ 27−	0·754*	49	− 9	40·4
	1845 III ☊ d*tL*	„ 31−	0·643*	47·5	− 6	39·0
(39, 45) 41	1854 IV ☊ *d*	Sept 10−	1·031*	53·0	−15	35·8
	„ III (Weiss)	„ 10−	1·018*	53·0	−15·8	34·8
42	1788 II ☊	„ 16+	0·808*	65	−45	25·2
Lexell's (31, 35, 53) 43	1770 I (Prhn.)	„ 17+	0·674	268	−18·5	10·4
(N. 19) 44	1763 ☊ L	„ 21+	0·98*	44	−23	28·8
	Do. (Weiss)	„ 20+	0·971	44·5	−24·1	27·8
(39, 41) 45	961 ☊	„ (13 to) 27−	0·975*	62	−13	34·0
46	1723 ☊ *t*	Oct 9−	1·065	112·5	− 7	40·5
(N 26) 47	1580 ☊? *D*	„ 16+	1·18*	61	−17	28·5
48	1779 ☊	„ 19+	0·974*	37	−27·5	18·7
	Do. (Weiss)	„ 19+	0·978*	39·2	−29·7	17·8
49	1585 ☊ d	Nov 4+	1·16	263	−39·5	11·6
50	1826 IV ☊	„ 7+	0·87*	32·5	−60·5	14·5
51	1707 ☊	„ 16+	0·910*	115	−32·0	32·0
52	1784 I ☊ d *t*	„ 20−	0·737	146·5	−18	40·3
Lexell's (31,35,43) 53	1770 I ☋ d *t l*	„ 29+	(−0·025)	257·5	−21	16·7
Blainpain's (2, 7, 55) 54	1819 IV ☊ *l*	Dec 10+	0·897	347·5	−36	11·0
	Do. (Weiss)	„ 9+	0·914	346·2	−44·5	6·6
Clausen's (2, 7, 54) 55	1743 I ? Ω	Nov. 13+	(−0·020)	21	+ 4·5	10·0
	„ ? ☊	Dec 21+	0·862§	7·5	− 2·5	10·4
56	1818 III ☊ *h*	„ 23−	0·868	168·5	−35·5	38·2
57	1863 IV ☊ d *t*	„ 29+	0·707	147·5	−57·5	28·7
4 *a*	1759 III Ω ‖	Jan. 19−	(−0·053)	210	−15	44·2
	Do. Perihel.	Feb 8−	(−0·07)	231	−21	44·1
	Do. Ω	Mar. 1−	(−0·084)*	253	−25	44·0
(N. 43 *a*) 11 *a*	1826 III ? ☋	Mar. 6−	(−0·076)*	215	−16	37·5
32 *a*	B.C. 370 ☊ ??	Aug. −	1·	25	− 5	39·5 ??

as excellently reproduced and completed up to a very recent date by G. F. Chambers in his 'Handbook of Descriptive Astronomy.' Orbits of comets of more recent dates (since the year 1866) were extracted from M. A. Guillemin's comprehensive and exceedingly accurate descriptive work 'Les Comètes.' The figures in the last column of the Table represent actual speeds of penetration or of flight through the atmosphere of meteoric particles proceeding from the comets, including the small additional velocities given to them by the earth's attraction. A Table for obtaining these, and complete Tables for other calculations included in these lists, are given (at the place above quoted) in Schiaparelli's work.

Researches on Meteorites, and accounts of their recent falls or discovery.—As will be gathered from the following abstracts of papers and communications relating to these subjects, great progress continues to be made in the investigation of the origin of meteorites, and of the circumstances which attend their fall. The first of these communications on the recent falls of Meteorites (Part I.), and that on the latest analytical researches and examinations of their structure (Part II.), contain descriptions of many such new occurrences and interesting observations on them which have hitherto been scarcely accessible to English readers, owing to the foreign languages and publications in which the original papers describing most of these particulars appeared; the following brief analyses and abstracts of their principal contents having accordingly been reproduced from his extensive summary of such recent contributions to aerolitic literature in the 'Geological Magazine' of the present year by Dr. Flight, they are presented here concisely and in a convenient arrangement for reference in this Report.

PART I.—METEORITES *which have been seen to fall, or have been found, between August* 1873 *and April* 1875. *By* WALTER FLIGHT.

1873, August 24th.—Marysville, California*.

All the facts that I have yet been able to gather respecting this fall are that an aerolite, weighing 12 lbs., crashed through the tree-tops with a bright flash, and was buried to the unusual depth of eight feet in the ground. When dug out it was so hot that it could not be handled.

Found 1873, August 27th.—Eisenberg, Saxe-Altenburg, Germany†.

A block of metal, weighing 1·579 kilog., was left exposed on the surface of the ground at the foot of the Schneckenberg, north of the Eisenberg, by a heavy thunder-shower washing away the surrounding soil. It is a finely granular iron, through which are disseminated here and there yellow particles of magnetic pyrites or troilite. Unlike metallic masses of undoubted meteoric origin, it contains neither nickel nor cobalt; when etched with nitric acid it exhibits, in place of figures, minute star-like forms. It has the composition:—

Iron	97·27
Phosphorus	0·21
Carbon	0·44
Silicic acid	1·50
Graphite	0·90
	100·32

The presence of silica was confirmed by treating the white, amorphous, somewhat rounded particles which remained undissolved with hydrofluoric acid.

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* Nature, 1st January, 1874. (From 'Iron.')

† H. B. Geinitz, 'Sitzungs-Ber. der Isis zu Dresden,' 1874–75.

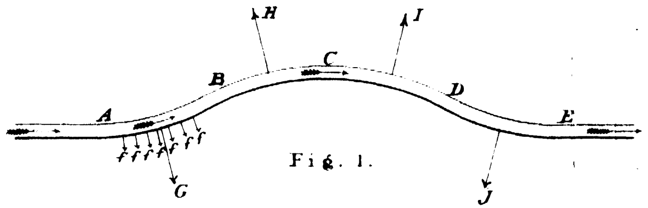
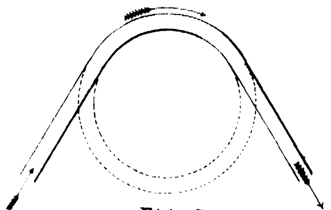


Fig. 1.



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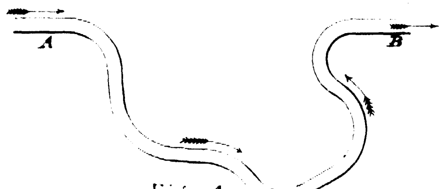

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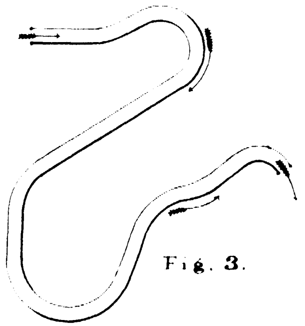

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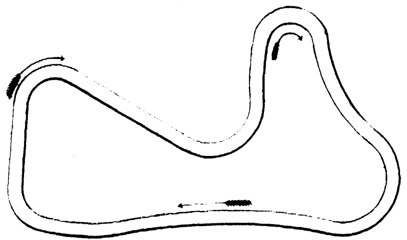

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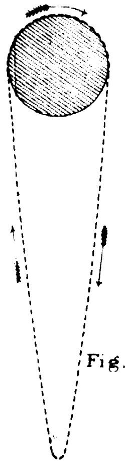

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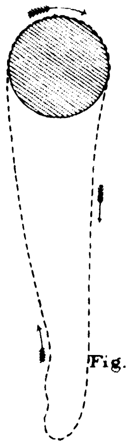

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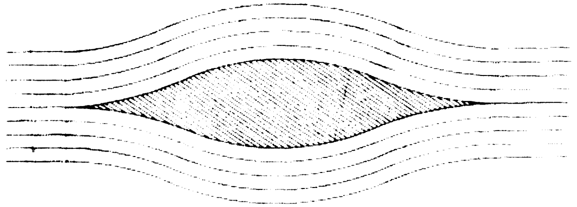

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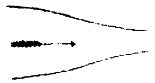

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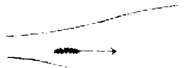

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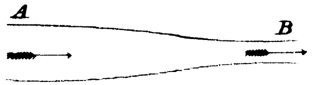

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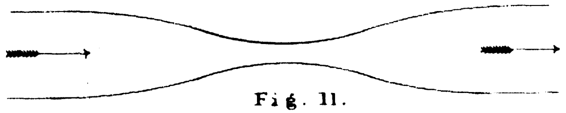

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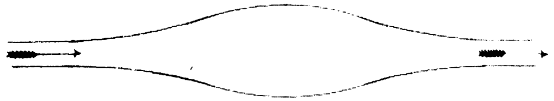

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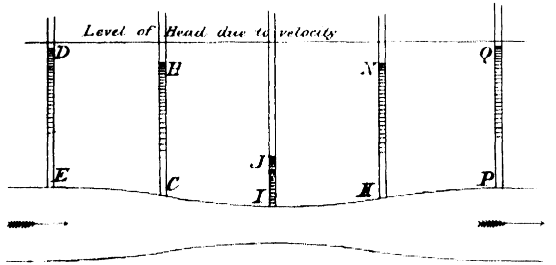
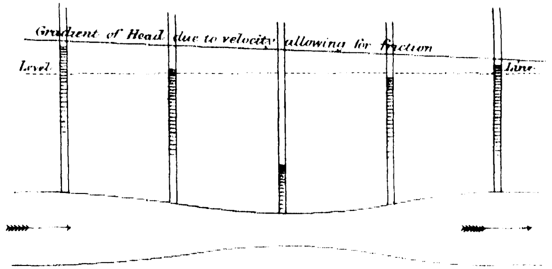


Fig. 14.



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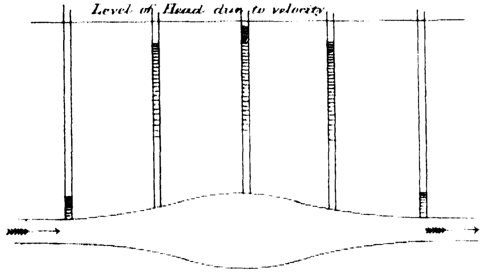

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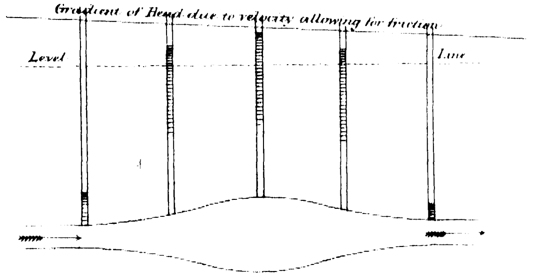

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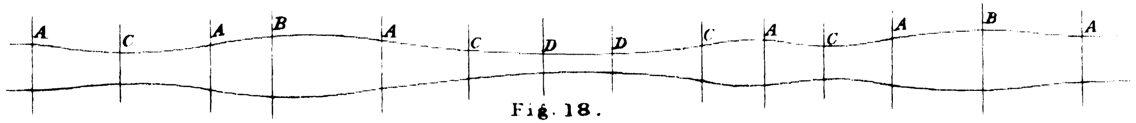

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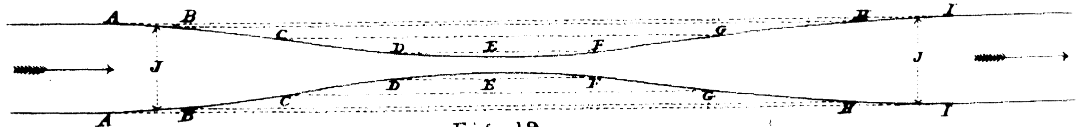
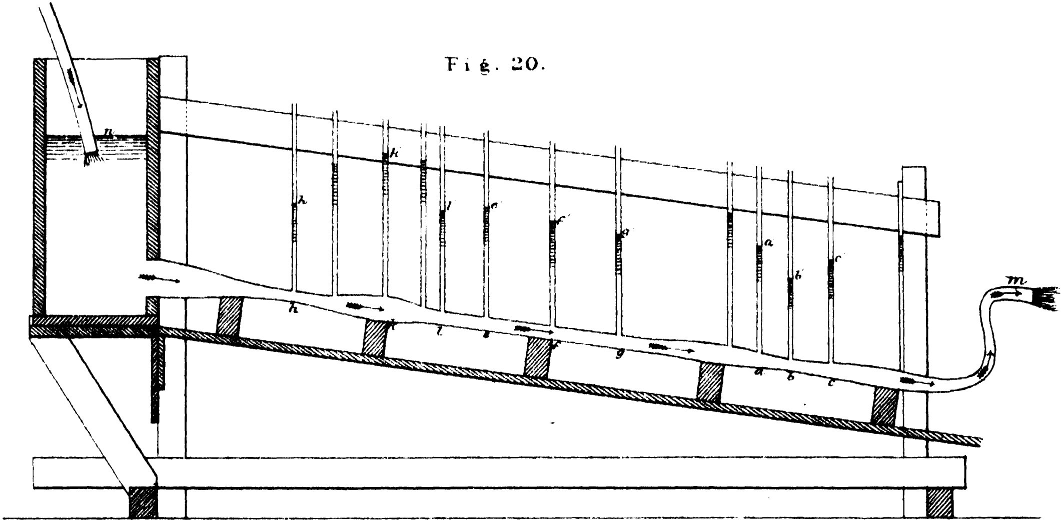


Fig. 19.

Newbery & Co 5, Castle St Holborn

Fig. 20.



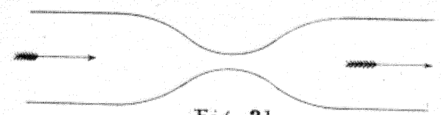


Fig. 21.

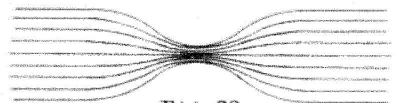


Fig. 22.

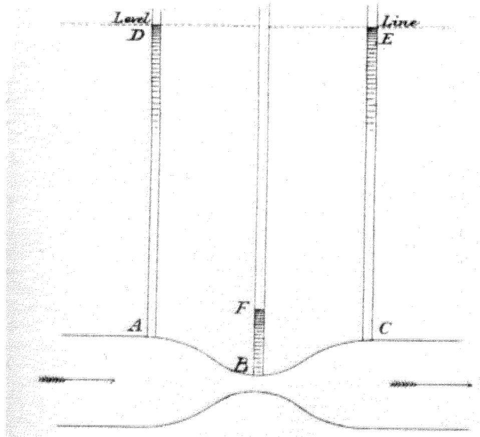


Fig. 23.

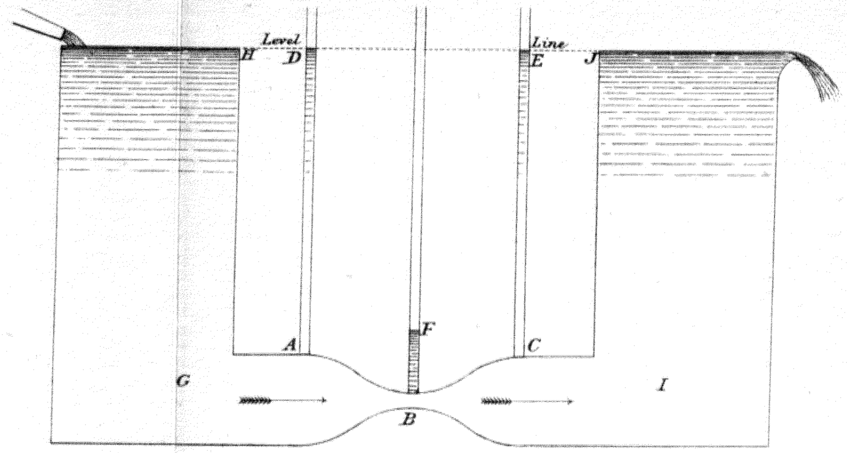


Fig. 24.

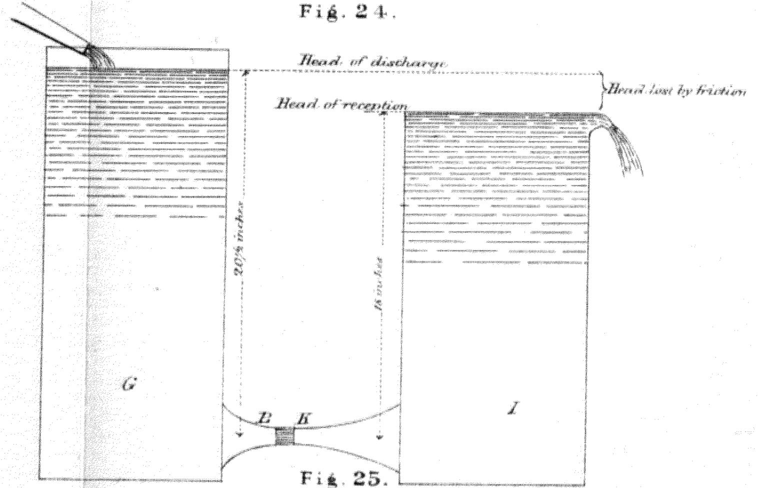


Fig. 25.

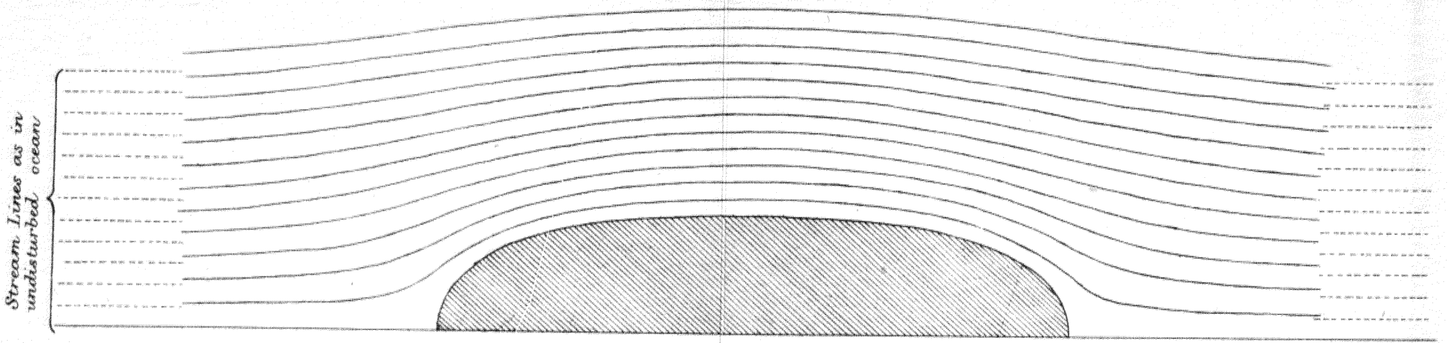


Fig. 26.

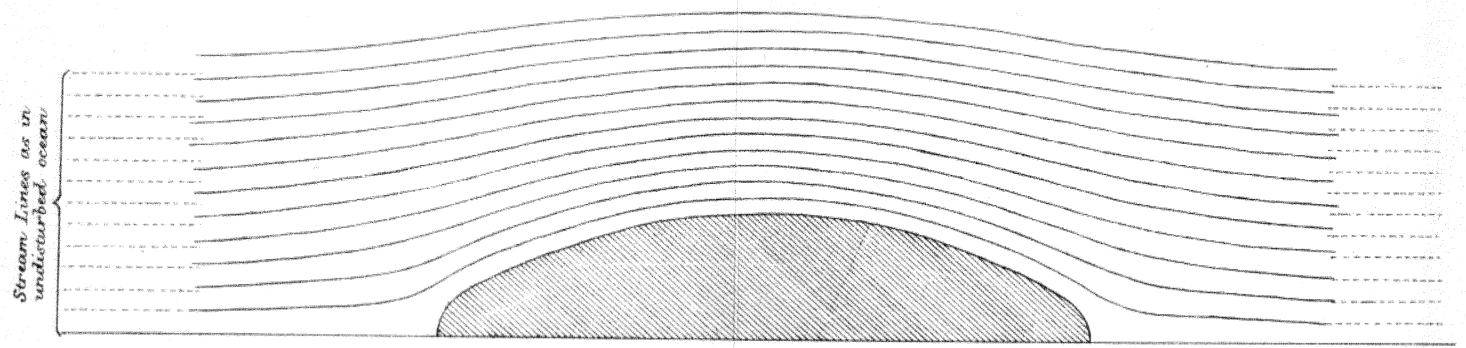


Fig. 27.

Note Figs 25, 26, The shaded figures are the horizontal sections of the submerged bodies, the depths of which must be supposed to be infinite, as the Stream Lines here shewn are what are called Stream Lines in Two Dimensions only, Such Stream Lines are more easy to understand than those which accompany Solids of Revolution.

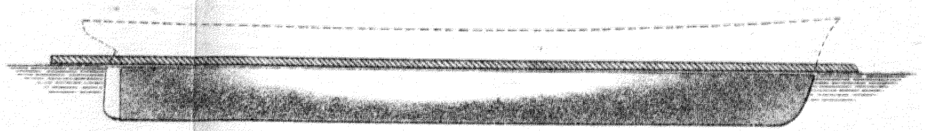


Fig. 28.

Assumed case of immersed portion of Ship travelling under a Sheet of rigid Ice.

Newbery & Co 5, Castle St Holborn

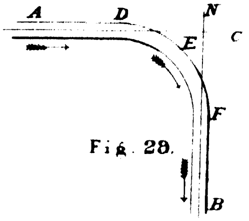


Fig. 29.

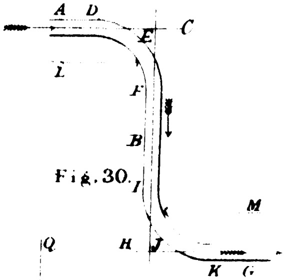


Fig. 30.

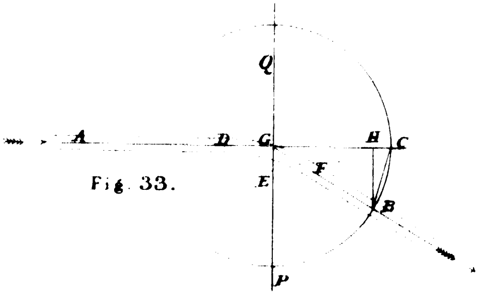


Fig. 33.

Let A C B = angle of bend

Let G C = force required to destroy the whole momentum of fluid in line A C

= tension which would be put on pipe A D by a right angled bend

Then H C = force required to destroy momentum lost at the bend in line A C

& H B = force required to establish momentum acquired at bend in line Q P

∴ B C = total force acting on pipe

This force must be in equilibrium with the tensions of pipe along B G & A C

∴ the tension of pipe = G C or G B

i. e. = the tension of pipe when the bend is right angled.

Therefore the tension of a bent pipe is constant for a given velocity of flow whatever be the angle of bend.

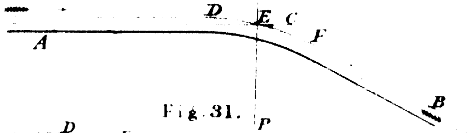


Fig. 31.

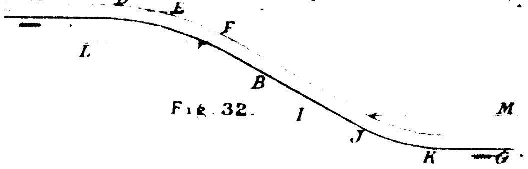


Fig. 32.

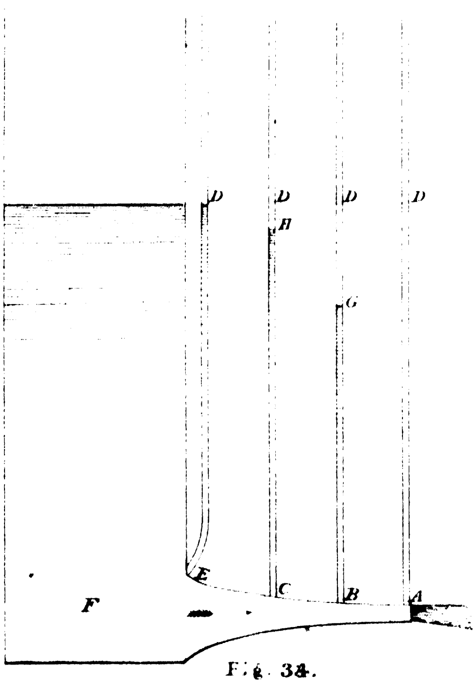


Fig. 34.

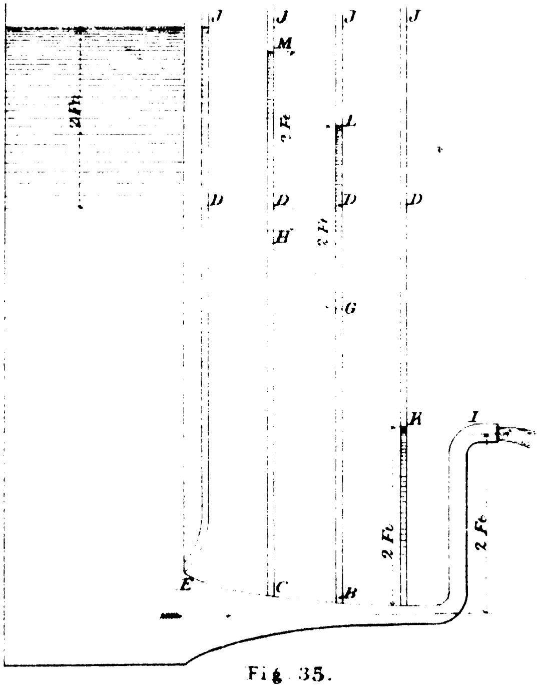


Fig. 35.

1873, September 23rd, 5.10 A.M.—Khairpur, 12 miles south of Multan, 36 miles E.N.E. of Bhawalpur, Punjab, India. [Lat. 29° 56′ N., long. 72° 12′ E.]*

A description of the meteor at Khairpur is given by the Rev. G. Yeates, similar in all essential details to that cited in these Reports (1874, p. 300), from the 'Astronomical Register,' with the addition that it first appeared near the star Algenib (about 15° above the west horizon) as a meteor,or rather cluster of meteors, each exceeding in brightness a star of the first magnitude; and the breadth of the train left behind them is estimated to have been from 3° to 5°. From this point "its motion was not very rapid but steady, and by the time it had reached about 10° of the meridian, which it passed south of the zenith, it assumed an exceedingly brilliant appearance, the larger fragments, glowing with intense white light with perhaps a shade of green, taking the lead in a cluster, surrounded and followed by a great number of smaller ones, each drawing a train after it, which, blending together, formed a broad belt of a brilliant fiery red." It lit up the whole country, and produced an effect similar to that of the electric light. It proceeded in this way, passing in its onward course close under Orion, the lowest star of which (Rigel) was very near the meridian, until it reached a point nearly due east, paling again as it drew near the horizon, and at about 20° above it appeared to go out rather than to fall. The train, which continued very bright for some time, was distinctly traceable three quarters of an hour afterwards. At first it changed to a dull red; then, as the morning broke, to a line of silvery-grey clouds that divided into several portions, and floated away on the wind. The track of the meteor was unusually long, extending through nearly 180°. The sky was cloudless, the morning being described as remarkably clear, with a faint glow in the east, the sun being still 45 minutes below the horizon when the meteor was first observed. After it had disappeared, and while the train still attracted attention, there was perfect silence, which was at length broken by a loud report, followed by a long reverberation, that gradually died away like the roll of distant thunder. This interval is estimated to have been four minutes.

At Bhawalpur the explosion was sufficiently violent to shake the houses and slam the doors. At Bhawalgur, 80 miles from Khairpur, the meteor was seen, but no explosion was heard. It was also observed at Jodhpur and Moradabad, and was probably visible within a radius of 300 miles round Khairpur.

A correspondent of 'The Pioneer' of the 30th of September records his observations made on the Shujabad road, 13 miles south of Multan. He states that the different fragments into which the meteor broke up were distinctly visible, "more than twenty of them, I should say, moving in parallel courses, two or three of the larger ones taking the lead in the centre, and each of them leaving a tail of red light behind," which blending together, formed one huge band of light. The report, which was very terrific, followed after the lapse of about three minutes and a half, which would make the point where the disruption of the aerolite took place about 42 or 45 miles distant. The train remained very bright for some time, and the clouds into which it was transformed were visible upwards of an hour afterwards, till they faded away in the bright sunlight.

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* H B. Medlicott, 'Journ. Asiat Soc. Bengal,' 1874, pt. ii. no ii. p. 33; 'The Pioneer,' Sept. 30th, 1873; Brit. Assoc Report, 1874, p 300.—The description by "G. Yates" (Astronom. Register, March 1874) appears to be compiled from two sources, that of Mr. Yeates's account above narrated, and that also quoted here, contributed by a correspondent to 'The Pioneer,' from a point of view between Multan and Shujabad.

Another correspondent, "Shikaree," states that on the left bank of the Chenab, some 60 miles S.W. of Bhawalpur, the meteor displayed great brilliancy, and that a double detonation followed after an interval of six or seven minutes.

One of the meteorites fell close to a man who had gone out into the jungle, and frightened him so much that he hardly knew what occurred, and was under the impression that the stone pursued him for two hours. He showed the spot where it fell, however, and this was the first fragment unearthed and forwarded by the Tuhsildar of Khairpur to Major Minchin, Political Agent for Bhawalpur.

The stones fell partly in the State of Bhawalpur and partly in the Multan district, on either bank of the Sutlej, over an area extending 16 miles in a direction bearing 35° S. of E., with a breadth of about three miles. The largest and perhaps the greater number fell to the eastward of Khairpur, and penetrated the earth to the depth of about 1½ foot. They are preserved in the following collections in India, and weigh respectively:—

	lbs.	oz.	grs.
Lahore Museum	10	12	126
Indian Museum	9	11	219
Indian Museum	7	14	236
Geological Museum .	1	2	412
Geological Museum . . .	0	3	79

Of those stones or fragments that fell on the Multan side seven have been heard of:—four at different spots near Gogewala well, E.S.E. of Mahomed Moorut; two at Khurampur, on the right bank of the Sutlej; and one at Araoli, two miles N.W. of Khurampur. Of these, one only is in known hands, that from Mylsi Pergunnah, which weighs 6 oz. 70 grs.

The account of the physical characters of the stones is very meagre. They are all very irregular in form, and are more or less broken. While some of the fractures have evidently been accomplished by hand, and others probably took place at the moment of falling, several appear to have occurred during the fall, as the glazed surface has been partially renewed. The stones are of the usual steel-grey colour and exhibit compact crypto-crystalline texture. One specimen has the specific gravity =3·66.

1873, December.—Coomassie, Kingdom of Ashantee, Africa[*].

In a letter from the War Correspondent of 'The Standard' it is stated that among the portents of evil which were observed at Coomassie while the British Army halted on the banks of the Prah, an aerolite fell in the market-place of Coomassie. In reply to an application for further details respecting this event, Mr. Henty writes that he obtained his information from one of the clergymen of the Basle Mission. He says:—"They mentioned these 'prodigies' as matters of common rumour and belief at Coomassie, but they do not appear to have even made any inquiries whatever as to their truth. Coomassie was deserted when we got there, so there was no opportunity of gaining further information."

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[*] G. A. Henty, 'March to Coomassie.' London: Tinsley Bros. 1874, p. 320.

1874, May 14th, 2.30 P.M.—Castalia, Nash Co., N. Carolina. [Lat. 36° 11′, long. 77° 50′.]*

A short notice in 'Silliman's Journal' states that the descent of these meteorites, numbering a dozen or more, was accompanied with a series of explosions and rumbling noises which lasted about four minutes, and were "not unlike the discharge of firearms in a battle a few miles off." Although the fall took place by day, a luminous body was observed. The area over which the fragments fell was ten miles long and three wide. Three stones, weighing 5·5, 1·0, and 0·8 kilog., have been found. The dull-coloured crust does not entirely cover the stones, the fused matter forming it being scattered over some small parts of the surface in the form of pear-shaped beads; in one or two crevices the fused material has penetrated 5 millims. below the surface, and here it is more brilliant than on the surface.

The colour of the interior is in many parts of a dark grey, owing to the presence of a larger amount of nickel-iron; in the lighter portions are seen some white spots of a mineral that is doubtless enstatite. The specific gravity of the stone is 2·601, and its proximate composition:—

Nickel-iron ..	15·21
Soluble silicate	44·92
Insoluble silicate ...	39·87
	100·00

The metallic part consists of

Iron = 92·12, Nickel = 6·20, Cobalt = 98·73;

and the siliceous portions of

	SiO_2	Al_2O_3	FeO	MgO	Na_2O	S		
A. Soluble	38·01	0·46	17·51	41·27	. ...	1·01	=	98·26
B. Insoluble ..	52·61	4·80	13·21	27·31	1·38	...	=	99·31

The soluble silicate is an olivine in which the ratio of MgO to Fe is about 4 : 1; the insoluble part is a bronzite; and in addition to the minerals already mentioned, the presence in the Castalia stones of small amount of iron sulphide and anorthite was recognized.

1874, May 20th.—Virba, near Vidin, Turkey†.

This meteorite fell with a loud noise, and entered the ground to the depth of one metre; it weighed 3·60 kilogs. A fragment presented to the Paris collection by His Excellency Safvet Pacha is covered with the usual dull black crust: a fractured surface shows the meteorite to have a light-grey colour and a very finely grained texture, with grains of metal distributed through the mass; in certain parts spherular structure is apparent. In a microscopic section it was found that the transparent and almost entirely colourless stony particles act on polarized light. The metallic portion is nickel-iron, the presence of an iron sulphide is recognized by the action of acid, and numerous small black grains of chromite are distributed throughout the stone. A part of the siliceous constituents gelatinize with acid, indicating the presence of olivine; and a residue, which resists the action and constitutes less than one half of the weight of the stone, is believed to be enstatite.

The Virba stone belongs to the large class of which the meteorite of Lucé, Sarthe, France (1768, September 13th), may be taken as the type; and is most closely allied to the aërolites of Bachmut, Island of Oesel, St. Denis Westrem, Buschof, Dolgaja Wolja, and those of other localities mentioned in Daubrée's paper.

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* J. L. Smith, 'Amer. Journ. Sc.' 3rd ser. vol. viii. p. 147.

† G. A. Daubrée, 'Comptes Rendus,' vol. lxxix. p. 276.

1874, August 1st, 11 P.M.—Hexham, Northumberland*.

In the 'English Mechanic' is a letter from a person signing himself "Ralph Lowdon," of Gateshead, stating that at the above time and place "a massive ball of intense light," accompanied by other pear-shaped balls of fire, was seen to drop towards the earth. The aerolite, which is alleged to have fallen in an orchard on the bank of the North Tyne, at no great distance from Hexham, is stated to have been found the following day at 9 A.M. at a depth of 14 inches in the soil, still quite warm, and to have weighed 301½ lbs. Letters directed to the above are returned by the Post-office authorities, while a courteous reply which I received from the Rev. H. C. Barker, of Hexham, states that the editor of 'The English Mechanic' must have been misinformed. The reverend gentleman writes:—"To make assurance doubly sure, I have made inquiry in several quarters, and cannot find even the slightest foundation for the statement."

1875, February 12th, 10.30 P.M. (Chicago time).—Iowa Co., State of Iowa†.

A very large and brilliant fireball passed over Iowa City at the above date, in a direction slightly N. of W.; the apparent size of the meteor was about half that of the full moon, and it was accompanied by a broad train of light of a slightly green hue. Three separate explosions of the fireball were noticed while it was still in view, and about two or three minutes after it disappeared three reports, resembling the discharge of the blast of a quarry, were heard.

The phenomenon attracted general attention throughout several counties in the central part of the State of Iowa; and although the visible path of the meteor does not appear to have exceeded 50 to 60 miles, the occurrence attracted attention and was heard over an area measuring about 125 miles from E. to W., and half that distance from N. to S. An observer at Brooklyn was aroused from his bed by the report; and another, who was riding in a sleigh near West Liberty, 40 miles E. of the spot where the stones fell, states that objects were rendered about as visible as if it were day, the explosions being loud, and followed by a rumbling sound that lasted some 60 or 90 seconds. According to the 'Grinell Herald,' the interval, as observed at that town, between the light of the meteor being seen and the report being heard was three minutes. The 'Des Moines Register' states that between Red Rock and Newton some of the meteorites passed so near the earth's surface that they clipped off branches from the trees.

Prof. N. R. Leonard, of the Iowa State University, states that the meteorites weighed altogether about 250 lbs., whereof 141 lbs. came into his possession; Prof. Hinrichs makes the total weight about 300 lbs The largest mass, which was broken in falling, weighed 43½ lbs., the chief fragments, found together, being 20 lbs. and 16 lbs. in weight.

According to a description, of a very sensational character, which is given in the 'Dubuque Times,' one of the meteorites was found in a field about three miles S. of the village of West Liberty, having penetrated, so it is stated, to a depth of fifteen feet into the ground.

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* The English Mechanic, August 21st, 1874.

† A. W. Wright, 'Amer. Journ. Sc.' ix. p. 459, and x. p 44. Cuttings from American newspapers and other communications to the Committee received from Mr. B. V. Marsh.

The 'Davenport Gazette' states that another stone fell at Homestead, near Iowa City (lat. 41° 46′ N., long. 92° 0′ W.), in a field covered with ice and snow, and rebounded in a N.E. direction for a distance of more than thirty feet up a slight declivity, where it came to rest in the sand, which was fused and adhering to it. It weighed originally about 7 lb. 6 oz., but had been reduced by eager curiosity-hunters to 3 lb. 8 oz.; the fractured surface of this meteorite had a dark and less distinct coating than that belonging to the larger block from which it had been detached by the explosion.

The stones are covered with the usual black crust, and there is evidence on some of the pieces of the meteorites of the fused material of the outer portion having run partially over the freshly fractured surfaces. Some fragments show distinct evidence of a sort of lamination or imperfect stratification, the parts where the surfaces cleaved being smoothed down as if by pressure or friction. About 100 were found, varying in size from 9500 to 50 grammes, 25 kilogs. having been sent to Paris. A preliminary chemical examination of this meteorite has already been made by L. Smith, who finds the specific gravity to be 3·57 and the composition:—

Nickel-iron =12 53, Troilite =5·82, Silicates =81·64: total 100·00.

The nickel-iron consists of

Iron=89·04, Nickel =10 35, Cobalt=0 54 total 99 93,

with traces of copper, phosphorus, and sulphur. The silicate contains iron protoxide, alumina, magnesia, soda, with traces of lithia and potash, and has, according to L. Smith, very similar compositions to the meteorite of New Concord, Guernsey Co., Ohio (1860, 1st May). Daubrée remarks on its chondritic structure, and considers it to belong to a large class of meteorites, notably represented by the stones which fell at Vouillé (1831, May 31st) and Aumale, Algeria (1865, August 25th).

This meteorite being of the stony kind, and having so recently fallen, it occurred to Wright (see also the examination of the Texas Meteorite, p. 244) to examine the gases contained in the particles of iron distributed throughout its mass, with a view to learning whether they present the same characters as the gases occluded by the iron forming large and independent masses.

He extracted from this picked iron at a moderately elevated temperature several times its volume of gas, consisting of 35 per cent. of carbonic acid, 14 per cent. of carbonic oxide, the remaining 51 per cent. being chiefly hydrogen. These results were obtained from metallic portions removed with the magnet: the pulverized rocky residue, however, retained a considerable amount of iron in too finely divided particles to enable them to lift the stony fragments adhering to them; accordingly a piece of the solid meteorite, about four cubic centimetres in amount, was reduced to powder and placed in the tube attached to the pump. The warmth of the hand sufficed to disengage some little gas, which, when tested, was found to contain carbonic acid and hydrogen. The pump was then set in action, and heat applied to the tube in the following manner:— I. The temperature of boiling water continued for several hours. II. The moderate heat (200°–250°) of a small Bunsen flame applied for a short time. III. A stronger heat, kept below visible redness, applied for nearly an hour. IV. Low red heat maintained about half an hour. V. Full red heat. The total amount of gas evolved was about two and a half times the volume of the material operated upon, and twenty times that of the iron. The following are the relative proportions of the gases obtained at different temperatures:—

	I. At 100°.	II. At 250°.	III. Below red heat.	IV. At low red heat.	V. At full red heat.
Carbonic acid	95·46	92·32	42·27	35·82	5·56
Carbonic oxide	0·00 ?	1·82	5·11	0·49	0·00
Hydrogen	4·54	5·86	48·06	58·51	87·53
Nitrogen (calculated)	0·00	0·00	4·56	5·18	6·91
	100·00	100·00	100·00	100·00	100·00

As regards the gas they occlude, iron and stony meteorites show a marked distinction. While the gases of the Lenarto iron contained 85·68 per cent. of hydrogen, those obtained from cosmical masses of the stony kind, if the Iowa meteorite may be regarded as a type, are characterized by the presence of carbonic acid, which constitutes nine tenths of the gas evolved at a temperature of boiling water, and about one half of that given off at a low red heat.

The spectrum of the gas of the Iowa meteorite, when the pressure of the pump was high, gave very brilliant carbon bands, the hydrogen lines being weak and comparatively inconspicuous, although at a very low pressure they became relatively stronger. The brightest carbon bands were the three in the green and blue, the red one being much feebler. These are precisely the ones most conspicuous in the spectra of some of the comets; and this fact is a remarkable confirmation of the received theory as to the meteoric character of those bodies.

This, moreover, is a very significant fact in showing that it is quite unnecessary to assume the existence of volatile hydrocarbons to explain cometary spectra, as some writers have done, and that the presence of the two oxides of carbon in such quantity is quite sufficient to account for all that has been observed when we consider the circumstance that the tension of the gases of the cometary appendage must be extremely small. Were a large comet to approach near enough to the sun to have its nucleus intensely heated, it is highly probable that, over and above the bands already observed, the hydrogen lines would be found in its spectrum.

Wright expresses regret that such a comet as Donati's should have departed into space just early enough to escape observation with the spectroscope. While the most probable cause of the emission of light under these conditions is electricity, another may be found in the property of gaseous bodies of emitting light of the same character as that which they absorb. It is not altogether improbable, Wright suggests, that the solar radiations absorbed by the gaseous matter, although for the most part converted into heat, would also in part be emitted again as light, and that in the case of volumes of gas filling many cubic inches, the intensity might be sufficient to give a distinct spectrum of broad bands or lines, even though, on the scale of any possible experiment, no trace of such an action can be detected. These researches have led the author to accept the following conclusions:—

1. The stony meteorites are distinguished from those which are metallic by occluding the oxides of carbon, chiefly carbonic acid, as their characteristic gases, in place of hydrogen.

2. The proportion of carbonic acid evolved is much greater at low than at high temperatures, and is sufficient to mask the hydrogen in the spectrum.

3. The amount of gas contained in a large meteorite, or a cluster of such bodies serving as a cometary nucleus, is sufficient to form the train as ordinarily observed.

4. The spectrum of these gases closely resembles that of several of the comets.

The emission of gaseous constituents by the action of solar heat may explain the loss of tail and the diminution of brilliancy observed in the case of several comets in their successive revolutions; and their final disappearance from sight will follow as an inevitable consequence, the number of revolutions necessary to discharge the gases depending chiefly on their size and the nearness of their approach to the sun at their perihelia. When a meteorite enters our atmosphere, the gases which are evolved from it by the heat which is liberated must greatly contribute to increase the intensity of that heat, while the sudden expansion which these gases experience must constitute the leading cause of the violent disruption of these masses.

1875, March 31st, between 3 and 4 P.M.—Zsadány, Temesvàr, the Banat, Hungary*.

No luminous meteor appears to have been observed at the time these stones fell; the day was bright and sunny and the sky cloudless. A sound as of platoon-firing was heard, and a small shower of black stones descended, some within the area of the village of Zsadány in the courtyards of the inhabitants, others in the open fields. They did not fall together, but at slight intervals, which appear to have been at least one third of a minute. Some were picked up immediately they reached the ground, and were found to be *cold*. It may be mentioned here that the stones which fell at Dhurmsala, in India† (1860, July 14th), are stated to have been so cold that they could not be held in the hand.

Sixteen stones in all have been found; the largest, having the size of a goose's egg and weighing about 152 grammes, is preserved in the National Museum at Pest; the remainder have an average size of a walnut, and their aggregate weight is nearly 400 grammes. Memák has sent a preliminary report describing the seven largest stones, illustrated with photographs of the four most interesting masses, to the Hungarian Academy of Sciences. The investigation of this aerolite has been undertaken by Wartha and Krenner; the former will subject it to analysis, the latter examine its mineralogical characters.

I learn, from an obliging letter received from Prof. Szabó, that these meteorites have a coarse-grained texture and are somewhat friable, and that they contain nickel-iron and scales of graphite.

1875, April 14th, 0.30 A.M.—Haddon, Grenville Co., Victoria, Australia‡.

A very brilliant meteor appeared from a bank of cloud about 20° above the N.W. horizon; it became elongated and pear-shaped as it traversed the heavens from W. to E., attaining an altitude of 50° on passing the zenith, where the nucleus appeared to break up and roll on in misshapen spheres of various sizes. On reaching a point within 20° of the N.E. horizon, the light became more intense and then the meteor disappeared. Eight or ten seconds later, reverberations as of thunder were distinctly heard. An eye-witness stationed at Haddon thought he saw matter fall near him, and the next day found a lump of melted matter, light in weight and of a nearly black colour, a portion being "a yellowish-brown substance like cinders from iron-smelting," as well as two fragments that were black, like coke, and a smaller fragment of a yellow hue. This great meteor, of which an engraving is given in 'The Illustrated Australian News,' was, it appears, observed in several parts of the country; but no other accounts of it indicating either the extent or position of its real course have yet been received.

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* Egyetértés és Magyar Ujság, 23rd April and June 16th, 1875.

† W. von Haidinger, Sitzungsber. Akad. Wiss Wien, xlii 305, xliv. 285. [It was a subject of frequent remark in conversation by Professor Brayley that the only foundation for this statement was a part of the native evidence collected on the occurrence of this stonefall, that the meteorite came "from the abode of snow"—a phrase which, in the native dialect, signifies a "northern direction," by a simple but direct allusion to the snow-topped summits of the Himalayas.—A. S H.]

‡ The Illustrated Australian News, May 17th, 1875, p. 68.—The same extract from this Australian newspaper was also obligingly communicated to the Committee by Mr. W. H. Wood (see the first Appendix of this Report).

PART II. METEORITES.—*Abstracts of papers published recently on Meteorites which either fell or were found before* 1874. *By* WALTER FLIGHT.

1808.—Red River, Texas*.

As Graham† has shown that the Lenarto meteoric iron contains 2·85 times its volume of occluded hydrogen, carbonic oxide, and nitrogen, and Mallet found 3·17 times its volume of hydrogen, carbonic oxide, carbonic acid, and nitrogen occluded in the meteoric iron of Augusta Co., Virginia, it occurred to the author that it might be possible to detect in the gas of these irons the unknown gaseous elements assumed to be present in the solar corona and chromosphere. The investigation was undertaken with the hope that the spectroscope would reveal them, if present, although their small amount or peculiar characters might render their detection by ordinary chemical methods difficult or impossible.

A vacuum-tube of the form ordinarily employed in spectroscopic work was attached to a branch of the exhaust-tube of a Sprengel pump, and a preliminary examination was made of the lines exhibited by this tube after simple withdrawal of the air. As Plücker and Hittorf‡ have already shown, lines of hydrogen and bands due to carbon make their appearance as soon as the limit of exhaustion has been attained; the author noticed the red hydrogen line when the tension fell to 4 or 5 millims. and other hydrogen lines when a higher degree of rarefaction was attained. Mercury lines, varying in brightness with the temperature of the room, are also to be seen. His investigations were directed to an examination of the gases of the great Texas meteorite preserved in the Mineral Collection of Yale College, and the meteoric iron of Tazewell Co. and Arva, Hungary (pp. 247, 248). The iron was in very small particles (chips produced by the borer), and the exhaustion was proceeded with without application of heat. He noticed that the iron gave off a portion of its gas at ordinary temperature; and when the tension was reduced to 4 millims., $H\alpha$ and $H\beta$ were bright and distinct, and $H\gamma$ visible while the carbon bands were also distinctly seen. When a gentle heat was applied, the tube, which had hitherto presented the appearance of an ordinary hydrogen tube, underwent a change; the light in the broad portion became a straight hazy stream, of a dull greenish-white colour, similar to that observed in a tube containing either of the oxides of carbon. When the tube containing the metal was raised to low redness, only a small quantity of gas was given off. Wright did not measure the amount of gas removed by the pump, but has calculated this quantity from an observation of the degree to which 1 cub. centim. of the gas lowered the gauge of the instrument. He finds in this way the mixed gases extracted to have occupied 4·75 times the volume of the metal. While this exceeds the quantity which Graham and Mallet noticed in their investigations, the author believes that the whole amount was by no means exhausted, and ascribes the excess to the fact of the metal which he used having been in a fine state of division.

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* A. W. Wright, 'Amer. Journ. Sci.' 1875, ix. p. 294.

† Proc. Roy. Soc. vol. xv. p. 502.

‡ Phil. Trans. vol. clv. p. 1.

1812, August 5th.—Chantonnay, Dép. de la Vendée, France*.

In the winter of 1874 Tschermak published a paper on the structure of the meteorites of Orvinio and Chantonnay, which appear to have many characters in common. Sections of the latter stone, three drawings of which are given in his paper, show it to be made up of chondritic fragments, covered with a dark-coloured crust, and cemented together with a black and in places semi-vitreous material. The fragments are not very abundantly provided with spherules, although large ones are here and there met with. It differs from the chondrite of the Orvinio meteorite in containing less iron; a section shows olivine, bronzite, a finely fibrous translucent mineral, as well as nickel-iron and magnetic pyrites. The presence of chromite was not recognized. Fine black veins of a mineral traverse the fragments here and there, and are connected with the cementing material. Similar veins are noticed in the meteorites of Lissa, Kakowa, Château Renard, Alessandria, and Pultusk; and in the Lissa and Kakowa stones they present the appearance as if the meteorite had originally come in contact with a molten material which had been injected into the clefts of its surface. Reichenbach was of opinion that the black veins were directly and intimately connected with the fused surface; his view, however, is open to question, from the fact that the interior of a meteorite has usually a low temperature when it reaches the earth's surface. Moreover, in the case of the Chantonnay stone, clefts are to be met with into which the black matter of the crust has penetrated to a depth of 6 millims. only, although the cleft remains partly open. The black semivitreous magma consists of an entirely opaque mass, enclosing flakes of the silicate which forms the fragments, as well as occasional spherules.

Although Rammelsberg, who analyzed this stone, does not describe the physical characters of the material he operated on, and did not separately examine the fragments and the cementing material, as Tschermak has done in his examination of the Orvinio meteorite, Tschermak points out that the two meteorites have much the same composition, and differ mainly in the proportion of iron. The characters observed in these two meteorites point to the conclusion that they did not originally possess their present constitution, but that by the disintegration of a solid rock-mass and its subsequent cementation with a semi-vitreous magma they attained their present appearance. Though they resemble somewhat the eruptive breccias, they differ from them in that the meteoric cementing material is less homogeneous, and encloses compact flakes of the rock itself. The Chantonnay stone exhibits the fine texture observed in some metamorphosed breccias. The two stones convey to us evidence of changes which must have occurred on the solid surface of some planet that was subsequently reduced to fragments.

1813, September 10th.—Adare, &c., Co. Limerick, Ireland†.

This meteorite, originally investigated by Apjohn‡, has been examined by R. Apjohn, who finds that it contains a trace of vanadium. The date which he assigns to the fall of this stone (1810) appears to be that of another Irish meteorite which fell at Mooresfort, Tipperary. The nickel-iron has the composition :—

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* G. Tschermak, 'Sitzungsber Ak. Wiss Wien,' lxx. November Heft, 1874.

† R. Apjohn, 'Journ. Chem. Soc' xii. p. 104.

‡ Apjohn, 'Trans. Irish Acad.' xviii. p. 17.

Iron =85·120, Nickel =14·27, Cobalt =0·602, Phosphorus=trace: total 99·997;

and the result of the treatment with acid :—

	SiO_2	Al_2O_3	FeO	MnO	CaO	MgO	Na_2O	K_2O	P_2O	
A. Soluble	42·91	2·35	16·93	6·26	5·34	24·32	0·29	0·02	. ...	= 98·42
B. Insoluble ...	59·48	3·24	7·94	8·84	4·62	13·17	1·86	0·30	trace	= 99·45

The mineralogical composition of the stone is stated to be :—

Nickel-iron	19·07
Chromite	1·75
Magnetic pyrites	6·54
Soluble silicate	35·44
Insoluble silicate	37·07
	99·87

The chromium oxide present as chromite is not mentioned at all in the above analysis. The iron sulphide is probably present as troilite (iron monosulphide mica, according to the older analysis). The greater part of the sulphur is in the part which is not attracted by the magnet. There the ratio is given as Fe=3·92, S=2·04; the percentages for troilite, using the sulphur as the basis for the calculation, would be Fe=3·57, S=2·04, and for magnetic pyrites Fe=3·12, S=2·04.

In a courteous letter received from the author he informs me that the amount of vanadium present was too small to allow of a quantitative estimation being made. He believes that in amount it is about half that met with in the trap-rocks of Auvergne, which have recently been examined by him. He is inclined to the belief that the vanadium is present as an oxide associated with the chromite, "for we know vanadium occurs in terrestrial chrome-iron in comparatively large quantities."

1835, July 31st or August 1st.—Charlotte, Dickson Co., Tennessee*.

The iron which is found disseminated in small particles throughout the mass of many meteoric stones represents in miniature the huge blocks of meteoric iron that from time to time have been met with on many parts of the earth's surface, the record of the fall of which is unknown, their descent having probably taken place at an epoch long anterior to that of their discovery. While the stones enclosing iron have not unfrequently been seen to fall, the descent of purely metallic masses has been rarely witnessed. At present we know of only the following few authentic cases :—Agram (1751), Braunau (1847), Victoria West, S. Africa (1862), Nidigullam, Madras (1870), and Marysville (1873). To these few instances is to be added the one heading this notice, of which a brief account was published by Troost, of Nashville, in 1845†. The Tennessee iron fell from a cloudless sky, near several persons who were working in the fields. A horse which was harnessed to a plough close by took fright and ran round the field, dragging the plough with it.

The iron has remained in the Troost Collection up to the present time, when it passed into the hands of Dr. Laurence Smith. It is a kidney-shaped mass, and has a bright surface like that of soft cast iron. When etched it exhibits Widmannstättian figures in great perfection, and the author states that in this

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* J. L. Smith, 'Comptes Rendus,' 1875, vol. lxxxi. p. 84.

† Amer. Journ. Sc. vol. xlix. p. 336.

Plate XIII

Fig. 1.

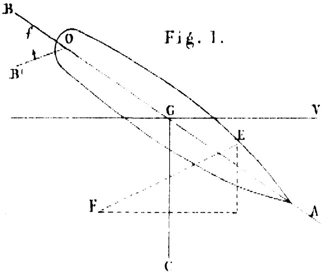


Fig. 2.

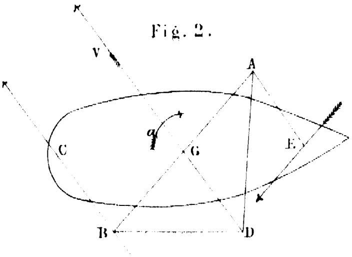
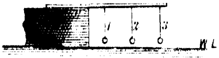


Fig. 3.



Bow of Boat showing position of weights.

Fig. 4.

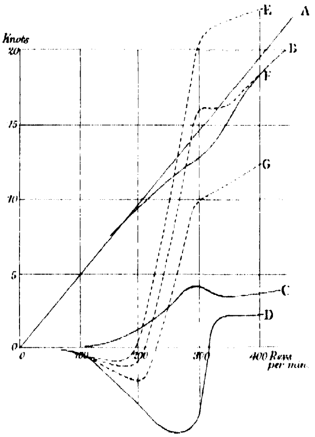
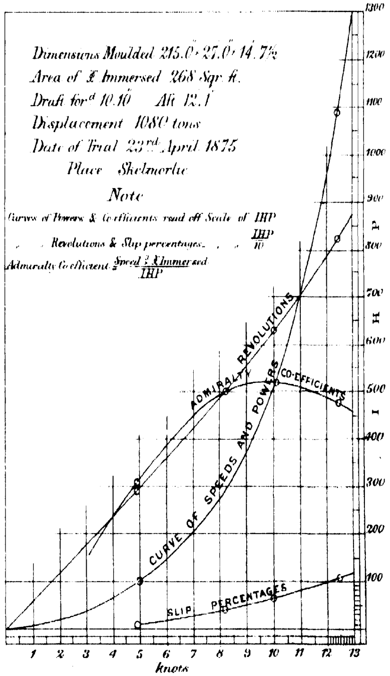


Fig. 5.

SPEED SCALE OF STEAMER "TAUPO"



respect he is acquainted with only three or four irons which rival it. An illustration accompanying his paper, closely resembling the one given by Troost, is a representation of the outer surface magnified; this is elaborately reticulated, edges of thin laminæ of metal, inclined at angles of 60°, traversing the surface, the edges being separated from each other by an apparently semi-fused slag-like material. The specific gravity of the iron is 7·717, and its composition:—

Iron =91·15, Nickel =8·01, Cobalt =0·72, Copper =0·06: total 99·94.

Sulphur is not present, and of phosphorus only a trace was recognized; and the author states that he has never before met with so small a proportion of this element in a meteoric iron. The gas extracted from this iron by A. W. Wright, who has recently examined the occluded gases of the irons of Texas, Arva, and Tazewell Co., as well as that of the meteorite of West Liberty, Iowa (which see), has nearly twice the volume of the metal operated upon, although this is probably a portion only of that actually present. It is composed of:—

Hydrogen =71·4, Carbonic oxide =15·3, Carbonic acid =13·3: total 100·00.

A question of no slight interest in regard to the changes which meteoric irons undergo during their passage through the atmosphere is whether their surface becomes fused. From his study of the Tennessee meteorite, Dr. Smith has decided it in the negative. The fact of the delicate reticulated surface having been preserved is a proof that the heat, instead of having been raised to a high temperature on the surface, has quickly been conducted away into the mass of the metal. Had fusion of the superficial layer taken place, the meteorite would have been coated with molten oxide.

The author finds in this fact a confirmation of his theory that the Ovifak masses are not of meteoric origin.

1840.—Szalnicza, Arva, Hungary[*].

For his investigation by means of the spectroscope of the gases occluded by meteoric iron, Wright examined those from the Red River, Texas, and Tazewell Co., Tennessee (which see below).

The amount of carbon present in the former iron was found on chemical examination to be very small; in the latter none was detected. A series of experiments were therefore made with the above iron, which, according to Lowe[†], contains a larger amount of carbon. While it was an easy task to remove fragments of the above-mentioned irons, great difficulties were experienced in the present case, the metal having nearly the hardness of steel. When the tube containing fragments of this iron was exhausted, and before heat was applied to it, the spectroscope indicated the presence in the "vacuum-tube" of both hydrogen and carbon gases; the lines of the former element were very brilliant, and the first, second, and third bands of the latter, counting from the red end, were visible. The application of a heat hardly sufficient to pain the hand caused an entire change in the appearance of the vacuum-tube; the broad part took a greenish hue, while in the spectroscope the carbon bands shone quite brightly. When the heat was raised to a temperature considerably short of redness, the only change noticed in the spectrum was a greater intensity of the carbon bands; the gas collected at this

[*] A. W. Wright, Amer. Journ. Sc. 1875, ix. p. 294.
Amer. Journ. Sc. [2], vol. viii. p. 439.

stage of the operation was found on analysis to consist of hydrogen, carbonic oxide, and carbonic acid, the latter amounting to three or four per cent.

In some experiments on artificial soft iron the author obtained a spectrum in every way similar to that of the meteoric metals; the hydrogen lines did not appear so early nor were they so bright as in the latter instances.

The iron of this meteorite, which by its great hardness was separated in the state of fine powder, yielded, when heated at different temperatures up to low redness, 44 times its volume of gas. While it seems not improbable that some portion of what has been occluded gas may have been atmospheric air, the yield is so unusually large that it suggests the question, May not the more perfect removal of the gas from the iron be due to the fine state of division of the metal operated upon? In the case of the Texas and Tazewell irons, where the yield of gas exceeded that obtained from the Lenarto and Augusta Co. irons, the metals were in very small pieces, which would favour a more refined and complete evolution of the gas; in the last-mentioned instances they were *en bloc*. That iron may under certain conditions, as when deposited by electrolysis, take up nearly two hundred and fifty times its volume, has been shown by the recent researches of M. Cailletet*. An observation recently made has a bearing on this question. While analyzing a specimen of silver amalgam, I endeavoured to remove from a weighed fragment of the mineral the mercury by heating the specimen in a hard glass tube for more than five minutes in the flame of the table blowpipe. The silver immediately fused and remained during that time in a molten state. When cold, the globule of metal was flattened into a plate, and having cut it into strips and subjected it to a second heating, I succeeded in removing a considerable part of a per cent. of mercury from it.

Wright's researches on the gases of meteoric irons have shown a varying character in the oxygen and nitrogen lines when in the presence of hydrogen, and the near coincidence of two of them with prominent lines in the corona, with the possible coincidence of a third line, which appears to indicate that the characteristic lines in the coronal spectrum are due, not so much to the presence of otherwise unknown elements, as to hydrogen and the atmospheric gases oxygen and nitrogen.

The observations were made with a spectroscope of six prisms with a repeating prism, giving the dispersion of twelve in all.

1853.—Tazewell, Claiborne Co., Tennessee†.

This meteorite was one of those selected by the author for his investigation with the spectroscope of the gases occluded by meteoric iron (see also the meteorites of Red River, Texas, and Arva, Hungary). It is noted for the large amount of nickel, 14·62 per cent., which it contains; it had been examined by J. L. Smith‡, who found no carbon in it. As in the case of the Texas meteorite, this iron appears to evolve gas before heat is applied; the red and green hydrogen lines were brilliant, while the bands of carbon were not noticed. When heat was applied, the spectrum showed the hydrogen lines very brilliantly, and the four chief carbon bands in great strength. As the tension of the gas decreased, the hydrogen lines became relatively stronger, and the carbon bands grew narrower; and at 1 millim. these bands were still prominent, and some narrow bands, apparently belonging to nitrogen, were observed. They differed, however, somewhat as to the order of their relative intensities from those observed with nitrogen alone. One of the lines appeared to coincide with the chief coronal line 1474 K, although not so sharp as the latter appears in the solar spectrum. An oxygen line likewise observed has the position 1462 K very nearly, and falls very near the position assigned to a bright coronal line by Denza and Lorenzoni when observing the eclipse of the 22nd December, 1870. A second oxygen line, less bright but sharp and distinct, has the position 1359 ± 1 K. The author directs attention to the complete change which the spectrum of an air-tube undergoes by the introduction of hydrogen. According to the method by which Wright calculates the amount of gas present in an iron (see the meteorite of the Red River, Texas, above), this metal occludes 4·69 times its volume of mixed gases. Although the greater part of the gas had been removed, the author is of opinion that the whole amount was by no means exhausted. The fact of the volume of gas in this instance being in excess of that obtained by Graham and Mallet probably arises from the Tazewell iron having been in a finely divided state.

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* L'Institut, nouv. sér. iii. p. 44.

† A. W. Wright, Amer. Journ. Sc. 1875, ix. p. 294.

‡ Amer. Journ. Sc. [2], vol. xix. p. 153.

1871, Spring of.—Roda, Province of Huesca, Spain[*].

The exact date of the fall of this meteorite is not given, but it is stated to have occurred during the spring of 1871, at a spot two kilometres from Roda. Two fragments in the possession of Pisani weigh about 200 grammes, and appear to have formed the half of a stone which was of the size of a fist. It is covered with a black crust, which is continuous and brilliant in places where this species of lustrous varnish has run. The interior is ashy grey, with greenish grains resembling peridot (some several millimetres in diameter) scattered throughout the mass. The grey surface is, however, not of a uniform tint, but presents two irregularly shaped areas, one being grey, the other yellowish grey. The stone is very friable, and has no action on the magnetic needle. Before the blowpipe it is fusible, becoming black and feebly magnetic.

Only a small portion, 14·75 per cent., of the meteorite is broken up by acid, that unacted upon amounting to 85·97 per cent. Below are given, in addition to the composition of the constituents separated by acid, the results of an analysis of the minerals constituting the mass of the stone:—

	SiO_2	Al_2O_3	Cr_2O_3	FeO	CaO	MgO	K_2O and Na_2O	S	
A. Soluble ...	38·85	4 81	.....	24·27	8 21	23 86	......	......	=100·00
B. Insoluble	52·93	1·95	0 39	16 29	1·92	26 52	.....	.. ...	=100·00
C. Total.. ...	51·51	2·30	0 34	17·04	2 31	26·61	0 80	0·40	=101·31

The soluble portion appears to be an iron olivine, mixed probably with a little anorthite; the insoluble portion consists chiefly of bronzite, or, according to Pisani, probably hypersthene, with the specific gravity of which mineral that of the meteorite more closely accords. The sulphur and the chromium are, it is presumed, present as magnetic pyrites and chromite; no nickel whatever was detected.

The yellowish green grains were very slightly attacked by acid, only 6 per cent. being soluble in that reagent. Their composition proved to be:—

Silicic acid	51 10	27 3	
Alumina	2 83	1·3	
Iron protoxide	27·70	11·1	14·9
Magnesia	17·20	3·8	
	98·83		

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[*] F. Pisani, 'Compt. Rend.' lxxix. 1507; G. A. Daubrée, 'Compt. Rend.' lxxix. 1509.

These numbers indicate, according to Pisani's view, the presence of a hypersthene rather than a bronzite, a hypersthene richer in iron than that of Farsund, Norway. The ratio of iron oxide to magnesia is the same as that in the bronzites of the Hainholz, Shalka, Borkut, and several other meteorites.

On some grains of this mineral a well-marked cleavage was distinguished along one direction; in others a disposition to cleave along a second direction was remarked: on examining such fragments in the polarizing microscope, however, one of the optic axes was almost always seen, while the other is invisible. The angle of the optic axes, as measured in oil, was approximately determined, making 2H=104°. The bisectrix is negative; but whether it was the acute or obtuse bisectrix was not determined.

This meteorite is remarkable for containing no metallic iron, and a very large proportion of bronzite or hypersthene.

Daubrée, during an examination of microscopic sections, noted many characters which favour the assumption that the chief constituent of this meteorite is bronzite rather than hypersthene. Such are:—the absence of dichroism, the frequent occurrence of the right angle in the contour of the crystals, and the fineness of the striæ, peculiar to bronzite. When magnified 800 diameters, most of the crystals are found to enclose yellowish brown rarely translucent matter, with very varied contour, and occasionally with a crystalline form, that of a modified oblique prism, which is that of pyroxene. They are ranged in rectilinear series, which are not always orientated parallel to the axes of the crystal. Here and there, adhering to the crystals, a brown vitreous substance, which is without action on polarized light, is seen; and in it occur cavities of relatively large dimensions, closely resembling those usually found in basaltic rocks. The Roda meteorite, with the single exception that it contains no iron, bears a great likeness to the meteorite of Lodran (1868, October 1st), and establishes a new link between cosmical rocks and those belonging to our planet. If, says Daubrée, we were to refuse to admit the testimony of those persons who affirm that they witnessed the fall of this fragment of rock, the characters of its crust would fully attest its cosmical origin.

1872. August 31st, 5.15 A.M. (Rome mean time).—Orvinio (formerly Canemorto), near Rome. [Long. 12° 36′ E., lat. 42° 8′ N.]*

A meteor was seen at daybreak by many observers in the provinces of Rome, Umbria, Abruzzo, and Terra di Lavoro. At first it appeared like a large star of a red colour. It increased in brilliancy as it traversed the sky in a northerly direction, leaving a white train. At a certain point it became brilliantly white, and then vanished, a luminous cloud remaining, which was visible for a quarter of an hour. The meteor appears to have crossed the coast-line at a point near Terracina, to have passed over Piperno in a direction 7° W. of N., and, moving N.N.E. over Cori and Gennazzano, to have exploded over the latter town. After the lapse of two to three minutes, two reports were heard, the first like that of a cannon, the second like a series of from three to six guns fired in rapid succession. The greater part of the stone fell at Orvinio, over which place the second explosion appears to have taken place, and some fragments were carried further northward.

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* A. Secchi, 'Comp. Rend.' lxxv. p. 655.—G. S. Ferrari, 'Ricerche fisico-astronomiche intorno all' Uranolito caduto nell' agro Romano il 31 di Agosto, 1872. Roma · Tip Blel. Arti, 1873.—P. Keller, 'Pogg. Ann.' cl. p. 171; 'Mineralog. Mitt.' 1874, p. 258.—M. Le Chevalier Michel-Etienne de Rossi and G. Bellucci, 'Atti dell' Acc. pontif di Nuovi Lincei,' 1873 —'Les Mondes,' 25th December, 1873.—L. Sipocz, 'Mineralog. Mitt.' 1874, p. 244.—G. Tschermak, 'Sitz. Ak. Wiss. Wien, lxx. November Heft, 1874.—These Reports, 1873, p. 384.

Six fragments of the meteorite, weighing collectively 3·396 kilogs., have been found:—No. 1, weighing 4¾ grammes, fell with a hissing noise near a peasant at Gerano; No. 2, weighing 92 grammes, fell at La Scarpa, within ten metres of a farmer, who picked it up while hot; No. 3, weighing 622 grammes, was found two or three days after the fall a few centimetres below the surface, in a stubbled field at Pezza del Meleto, between Orvinio and Pozzaglia; No. 4, 1242·5 grammes in weight, was found a week after the fall, close to Orvinio: the grass around it had been somewhat singed; No. 5, weighing 432 grammes, was picked up a week after the fall at Pezza del Meleto; No. 6, weighing 1003 grammes, was found on the 8th of May, 200 metres distant from No. 4, at a very trifling depth, while turning up the soil of a field.

At the time of the fall a man was passing the spot where fragments numbered 4 and 6 were found. Immediately after the explosion, he heard the sound of a heavy body striking the earth, and he fell on the ground with fear. At the same time, or a little later, a fire broke out in a barn filled with hay in the village of Affile, and the occurrence was, with general consent, ascribed to the meteorite.

In September 1873 Keller learnt that two more small fragments had fallen near the village of Anticoli Corradi. The one fell near two boys who were tending cattle. They became alarmed at the hissing noise, and believing this projectile to be aimed by the devil, they picked it up, and threw it far away from them. The other stone was observed to fall on the bare rock, and to break in pieces. The fragments were collected; but as they were held to be of no value, they were subsequently lost. In the case of this aërolite, as in that of others, the smaller appear to have fallen before the larger fragments.

The velocity of this fall must have been very slow. The authors do not state whether any of the fragments could be fitted together; their specific gravity ranged between 3·58 and 3·73—in one, richer in metallic constituents, it amounted to 4·598. Two of the fragments bear portions of the crust lying in pits and hollows. It is only ½ millim. thick, has a pitch-black colour, and exhibits in some places a waxy lustre. The mass of the stone is of a lead-grey colour, being darker than that of the aerolites of Pultusk and Monte Milone. A polished surface exhibits metallic grains, some 2 millims. in diameter, and a green silicate, probably olivine. The ground-mass appears to be made up of two minerals, one clear and uniform, the other dull and less homogeneous. The stone acts powerfully on the magnet.

In Ferrari's memoir is given a plan of the country near Rome, on which is indicated the track of the meteor and the positions where the stones fell. The line of flight, a singularly devious one, is seen to pass immediately over the summits of M. Leano, M. Sempreviso, M. Lapone, and quite near to that of M. Gennaro, the chief mountains of the district, and suggests (although obviously only by appearance) the gravitating action of these more elevated masses of the earth's surface on the path of the meteor. A sketch of the latter, the trajectory of which is computed to have been inclined 27° to the plane of the horizon, accompanies the map.

The paper of M. Le Chevalier Michel-Etienne de Rossi gives the analysis and observations of Prof. Bellucci, of Perugia. When heated to 120° the powdered mineral lost 1·875 per cent., and by treatment with water a little potassium and sodium chloride were dissolved. (Compare with Daubrée's examination of the Lancé stone.) The magnet removed 29·04 per cent., and acid 45·04 per cent. The analysis of a portion of the stone gave the following numbers:—silicic acid=46·72, alumina=16·84, magnesia =1·97, iron=25·59, iron oxide (*fer oxidé*)=4·82, sulphur=2·24, nickel with trace of cobalt=1·37, with traces of calcium, chromium, manganese, arsenic, and phosphorus. Two points are worthy of remark in this analysis: first, the astonishingly large amount of alumina present, far in excess of that found in any other meteorite. In the absence of a second and confirmatory analysis, it may be assumed that insufficient ammonium chloride was employed, and the greater portion of the 16·84 per cent. is magnesia, which was precipitated with the alumina. Secondly, the occurrence of arsenic, which is of extreme rarity in a meteorite; it is stated to be present in the iron of Braunau and the olivine of the Atacama siderolite.

Tschermak's report of his examination of this stone appeared in the winter of 1874. The structure developed on cutting the stone is unusual and remarkable, consisting of light-coloured fragments (I.), surrounded by a compact dark cementing material (II.). The former are yellowish grey, enclose spherules and particles of iron and magnetic pyrites, are, in fact, normal chondrite, and resemble the mass of the stone which fell at Seres, in Macedonia (1818, June). The latter encloses numerous particles of iron and magnetic pyrites, for the most part uniformly distributed; the portion nearest the enclosed fragments bears very distinct indications of having been at one time fluid, and conveys the impression that this cementing material was at one time in a plastic condition while in motion. Along the boundary of these two very dissimilar portions flaws are seen, in which nickel-iron has crystallized in delicate plate-like forms; and here, moreover, the fragments are darker, harder, and more brittle than those of the centre, which argues the exposure of the cementing material to a very high temperature while in a plastic condition. Both portions have nearly the same density and apparently the same chemical composition and mineral characteristics. The Orvinio stone resembles, in fact, certain brecciated volcanic rocks, which consist of a groundmass through which granular fragments of the same rock are distributed, as when older crystalline lavas are interpenetrated by others more compact and of a more recent period.

The light-coloured fragments are, as has been stated, chondritic; the spherules are usually of one kind, lying in a splintery matrix of the same mineral, containing some nickel-iron and magnetic pyrites. Among the transparent constituents, olivine is recognized by its imperfect cleavage; a second mineral, with a distinct cleavage along a prism of nearly quadratic section, is evidently bronzite; while a third, which occurs in fine foliated or fibrous particles, may be either identical with the above or be a felspathic ingredient.

The meteoric rocks possessing chondritic structure are regarded by Tschermak as tufas which have undergone detrition, and their spherules to be such particles as, by their superior toughness, have, during the trituration of the rock, instead of breaking up into splinters, acquired a rounded form.

A black material is observed to coat the fragments of the rock and to fill the finer flaws existing between them, whereby their transparent character is considerably impaired; this has also been noticed in the meteorite of Tadjera (1867, June 9th).

The dark-coloured cementing material contains two ingredients: an opaque semivitreous constituent, and particles in every way similar to the dark crust of the fragments from which they may probably have been detached; many of them can still be recognized as olivine and bronzite. The nickel-iron and magnetic pyrites of this portion of the stone are more finely divided than in the fragments, and have often a rounded form. The metal of this portion, as well as in the other, exhibits no Widmannstättian figures; but in both, by treatment with acid, lines are developed like those of the Braunau iron.

The two species of rock, the chondritic fragments (I.) and the darker cementing material (II.), have the following composition:—

	I.	II.
Silicic acid	38·01	36·82
Alumina	2·22	2·31
Chromium oxide	trace	trace
Iron protoxide	6·55	9·41
Magnesia	24·11	21·69
Lime	2·33	2·31
Soda	1·46	0·96
Potash	0·31	0·26
Iron	22·34	22·11
Nickel, with trace of cobalt	2·15	3·04
Sulphur	1·94	2·04
	101·42	100·95
Specific gravity	3·675	3·600

These results establish the similarity in composition of the two portions, and, as Tschermak points out, the erroneous character of Bellucci's analysis, to which attention has already been directed.

Tschermak's paper is illustrated with a plate, giving a figure of the meteorite he examined; a drawing, actual size, of the section, showing very distinctly the appearance of fusion; and three microscopic sections, magnified 20 diameters, of the two rock varieties composing the greater part of the stone.

PART III. *Recent contributions to Aerolitic literature.* *By* A. S. HERSCHEL.

In the foregoing *résumé* it will be seen that the annals of meteoric falls increase yearly in numbers and extent, and that a leading clue to the explanation of these phenomena is presented by the frequently recorded falls of meteorites in every continent of the globe. The researches of Howard and Vauquelin, of G. Rose, Wöhler, Reichenbach, Rammelsberg, Tschermak, Daubrée, L. Smith, and Silliman, and, returning from the first of these to our own countrymen, of Maskelyne and Sorby, have rendered modern mineralogists so familiar with the nature, both structural and chemical or elementary, of these mineral fragments scattered and imported from distant spheres to the surface of our globe, that the views presented by these numerous investigations cannot fail to give a strong impulse to questions in the solution of which cultivators of every science must feel an interest, and promise great achievements in the future discoveries of astronomy. Not only is a kindred character met with among the fragments occurring thus problematically for examination, but again this type itself is kindred to that of materials which are substances of familiar occurrence in terrestrial rocks, and the majority of stony meteorites are themselves tufaceous or brecciated masses of obviously volcanic production. That they enclose metallic iron and nickel, and that they sometimes consist of these metals in a solid mass, is not a complete anomaly even in terrestrial geology, if the inquiries in course of prosecution on the sites of discovery of the irons of Pallas and Ovifak, supposed to be meteoric, should (as appears probable) bear out a different conclusion. But in the progress of chemical and microscopical inspections of their substance, numerous peculiarities are perceived in meteorites which, as strongly as the prevalence of metallic ingredients, contribute to distinguish them from terrestrial volcanic rocks. The early detection of olivine, and the separation of augite and (?) labradorite or anorthite (a felspar), in the meteorite of Juvinas, succeeded more recently by the distinction of enstatite and olivine as the major constituents of stony meteorites, and finally (steps which we owe to the chemical separation and skilful detection of these minerals by Maskelyne with the polarizing microscope) the recognition of enstatite and its ferro-magnesian variety bronzite as the usual representatives of the "insoluble," combined with the basic mineral olivine as the "soluble" silicate entering into their ordinary composition, forms the substructure upon which the chemical analogy of their composition with terrestrial basalts in the many varieties which are met with among the class of stony meteorites is at present based. A system of structural classification according to the amount and mode of dissemination of the metallic iron, devised by Daubrée for the totality of meteorites, and the distinction of "chondritic" structure in aërolites or in the stony portions of a great number of meteorites by Reichenbach, forms, on the other hand, a ground-plan upon which their mineralogical description and microscopical examination are conducted,—all aerolites and stony parts of meteorites (with exception, perhaps, more or less, of the carbonaceous aerolites) not of this description consisting in general of finely brecciated, splintered and shapeless, cemented or otherwise consolidated crystalline fragments, those aerolites being termed chondritic which enclose scattered through their mass a number of rounded grains or spherules. To these ordinary characters of structure and composition many subordinate features are also frequently superadded, as the presence of graphite, troilite, and magnetic pyrites, magnetite, chromite, schreibersite, and of some rarer but equally distinct minerals, as azmanite, oldhamite, &c., and of gases occluded in the metallic portions of the stones; and, again, the crystalline structure of the latter portions, as exhibited in Widmanstättian figures by etching their cleanly polished surfaces with mercuric chloride or with dilute acids, together with the vitreous or crystalline characters of the spheres or fragments and of the cement composing the non-metallic portions of the meteorite, in the detection of which thin sections of it are employed, and both the microscope and its powerful auxiliary polarized light lend important aid. In all these methods of interrogation and of systematic description great progress has recently been made, to describe at length the various results of which would here occupy too large a space. The subject has been ably handled by Dr. Flight in a series of articles in the 'Geological Magazine' of the present year (January–August, 1875), and more than a reference to its copious information in a fifteen years' recapitulation of the united progress of similar investigations need not be offered in this Report as a sufficient recommendation for its perusal. As a separate treatise on the subject to which its further Parts are intended to contribute, it may be indicated as the source in which, since the close in the year 1860 of Dr. Buchner's chronological work on 'Meteorites,' students of this department of science (at least in the English language) will find the readiest assistance for their information and guidance in the recent abundant development of these inquiries.

In the valuable recently commenced Annual Record of contemporary papers bearing on the progress of Geology, the first volume of which is announced at the present Meeting of the British Association as being nearly completed and ready for immediate publication, the Committee has also the gratification to observe, in the Section devoted to Petrology, a copious abstract, chiefly from the pen of Dr. Flight*, of analyses and mineralogical examinations during the past year of a great number and variety of meteoric products. In addition to those above described of the meteorites of Orvinio, Roda, Lodran, Adare, and of several meteoric irons, the leading particulars of which are given, some recent observations by Nordenskjold on snow-dust gathered from the névés of various climates are noticed, with its probable relation to meteor-dust in the atmosphere and to the blue colour of glacier-ice. The whole of these short abstracts, occupying several pages of the printed volume, are full of concise and useful information on the advance and progress which have been made in the various departments of meteoric mineralogy during the brief interval of the past year.

A speculative paper on the origin of meteorites by Dr. G. Tschermak† expresses very clearly the author's views on the present aspects of knowledge regarding their history, and presents a number of important remarks on their formation. The spectroscope has confirmed the earlier conjectures, derived from a study of meteorites, of a prevailing similarity of materials in the chemical elements of the heavenly bodies; and from the forms of meteorites it may be expected that a knowledge of the processes to which they have been subjected may be derived. Apart from their minute internal structure, it is certain that externally they are acutely angular fragments, evidently of a large planetary mass, and (as shown by the crystalline structure of meteoric irons and by sliding faces in some aerolites) of a large cosmical body where uniform temperature and long periods of tranquillity have prevailed. Their internal structure, exactly analogous to that of our volcanic tufas, is another evidence of the same conclusion; and Daubrée regards collisions or explosions of such large cosmical bodies as the origin from which they sprang. But as their proportions are always diminutive or dust-like in comparison to the parent-bodies, explosive rather than disruptive agencies, or projectile forces acting from within outwards locally upon the bodies, appear to have ushered their ejected fragments into cosmical revolutions. With regard to their internal structure, a further acquaintance with these "star-masses" before their disintegration is afforded to us by a close examination. Their porous materials, made up of pulverized rocks, were correctly pronounced by Haidinger to be volcanic products, which may be characterized as meteoric tuffs. Spherular forms are of widely spread occurrence among their triturated grains, quite round and unconformably crystallized with regard to their figure, when the materials are tough, and varying in size from microscopic dust to that of small bird-shot or millet-seeds; round fragments as large as a cherry are of rare occurrence; but in the volcanic rocks of our globe they ordinarily occur in sizes varying from that of a hazel-nut to that of a bead. Numberless small volcanic fissures, it may be conjectured, contribute to their ejection; and in no meteorites do we trace the appearance of slag-like rock enclosing well-developed crystals which their formation from lava would lead us to expect. An example of a true crater of explosion without ejection of lava is furnished by the Eifel; and in planetary bodies, where evolutions of occluded gases play a prominent part in the disturbances of the surface, the projection of such fragments as we find in meteorites from active volcanic craters may not be an unnatural or altogether improbable hypothesis of the kind of action of physical forces concerned in their formation.

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* 'The Geological Record for 1874: an account of Works on Geology, Mineralogy, and Palæontology published during the Year.' Article "Petrology," p. 216. London: Taylor and Francis, 1875.

† "Die Bildung der Meteoriten, und der Vulkanismus," Vienna Acad. Sitzungsberichte, 1875, pt. ii. April 1875.

In the 'Astronomische Nachrichten' (No. 2064), Herr N. v. Konkoly describes results of some spectroscopic observations of the Perseïds of August 1874, examined by means of a Browning's meteor-spectroscope. The spectra of 130 meteors on the nights of the 7th, 8th, and 10th to 12th of August, varying in brightness from 1st to 4th magnitude stars, showed continuous colours, yellow and green predominating chiefly in all the nuclei, violet being always and indigo mostly absent, and red only bright in those which were markedly red-coloured. The spectra of the streaks were very various, those of distinctly yellow meteors showing only the double yellow line of sodium (always present in the streaks, and serving as a micrometric zero from which the positions of the other bright lines could be relatively estimated). In the streak-spectra of green meteors the green lines of magnesium were also visible; and in some of red colour red lines, apparently those of strontium, or of strontium and lithium, were observed. Some of these meteors were brighter than Venus, and left streaks which lasted for 30 or 40 seconds. The streak of one which remained visible for 156 seconds was observed with the spectroscope for 30 seconds. Not only the bright lines of sodium and magnesium, but many other bright lines, especially in the green, and some also in the blue, were seen, which were regarded as probably due to the presence of iron and copper in the substance of the streak; a cotton-ball dipped in alcohol and inflamed, having particles of sodium, magnesium, and iron with very little copper in its fibres, exhibited, when tossed into the air, a very similar spectrum, while no other combination tried produced a similar effect.

The following important paper by Dr. G. Tschermak on the meteorites of Lancé (1872, July 23rd) in the fifth volume (pt. i. Jan. 1875) of his 'Mineralogische Mittheilungen,' shows that (as was found by Daubrée in the meteorites of Aumale, 1865, Aug. 25th) aerolites that fell about the period of the August meteor-shower have more than once presented the rare occurrence of sodium chloride in their composition. The appearance and general course pursued by this fireball is described with unusual completeness in a work by M. Nouel*, of Vendôme, in the neighbourhood of which town the meteorites fell; and the fireball was very generally observed.

Dr. Tschermak's paper treats of the chemical analysis and of the microscopic examination of thin sections of the stone; and besides eleven admirable lithographic representations of the latter, it contains three plates of the external appearance of the largest of the stones (found in three pieces at the bottom of a hole 1½ metre deep) from different points of view, the directions of the slag-fibres on its crust showing clearly how the front or pyramidal part and back or flattened base of the stone had been differently exposed to the rushing and smelting blast of heated air through which it forced its way point foremost with apparently only one or two slight oscillations. The drawings of thin sections exhibit microscopic views of spherules of great variety, of a clear olivine crystal, and of one (*the only unrounded one* observed) of bronzite. Among the spherules a remarkable one of bronzite is immediately recognized by the numberless cleavages and cross cleavages exhibited by its structurally prismatic crystal. Other spherules are of transparent olivine without radial structure; and some are of highly composite characters, appearing occasionally to have been incrusted or metamorphosed externally and concentrically to a certain depth, but found by polarized light to possess only apparent radial and in reality excentrical crystalline structure when submitted to this test. The spherules do not exceed 1 millim. in diameter. Iron and iron sulphide are disseminated through both the spherules and pulverized ground mass, the latter compound sometimes forming grains and spherules about which metallic iron has incrusted, and conversely; and the general character of the meteorites is that of the minutely chondritic class.

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* Notice sur le bolide du 23 Juillet 1872 qui a projeté des météorites dans le canton de St.-Amand, arrondissement de Vendôme, département de Loire-et-Cher, par M. Nouel. Vendôme, 1873.

Water dissolves out from the stones 0·12 per cent. of sodium chloride, which can also be sublimed from them in a hydrogen atmosphere at a red heat; and the presence of a trace of copper can be detected by the aid of a spectroscope. Besides metallic grains of iron (7·81 per cent.) containing nickel and cobalt and iron pyrites (14·28 per cent., no troilite or iron monosulphide, it appears, occurring in this aerolite), and 1·36 per cent. of sodic chloride and hygroscopic water, there was found 42·44 per cent. of silicates soluble, and 33·34 per cent. insoluble (probably including chromite) in hydrochloric acid; total (with loss 0·66 per cent.) 100. Of the latter silicate or bronzite no analysis is given; but of the soluble silicate the following was the composition :—

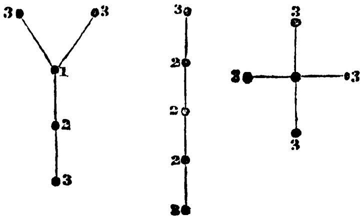
SiO_2.	MgO.	FeO.	MnO.	Total.
17·20	13·86	11·33	0·05	42·44

and no traces of calcium, barium, or strontium were detected in the stone. A perfectly similar chemical analysis of the same meteorite by Dr. R. von Drasche is added by Von Tschermak to the above account of its mineralogical examination and description.

On the Analytical Forms called Trees, with Application to the Theory of Chemical Combinations. By Professor Cayley, *F.R.S.*

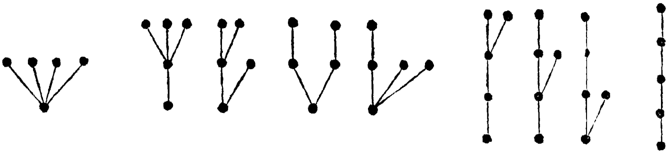
[Plate VIII.]

I have in two papers "On the Analytical forms called Trees," Phil. Mag. vol. xiii. (1857) pp. 172–176, and ditto, vol. xx. (1860) pp. 337–341, considered this theory, and in a paper "On the Mathematical Theory of Isomers," ditto, vol. xlvii. (1874) p. 444, pointed out its connexion with modern chemical theory. In particular as regards the paraffines $C_n H_{2n+2}$, we have n atoms of carbon connected by $n-1$ bands, under the restriction that from each carbon-atom there proceed at most 4 bands (or, in the language of the papers first referred to, we have n knots connected by $n-1$ branches), in the form of a tree; for instance, $n=5$, such forms (and the only such forms) are



And if (under the foregoing restriction of only 4 bands from a carbon-atom) we connect with each carbon-atom the greatest possible number of hydrogen-atoms (as shown in the diagrams by the affixed numerals), we see that the number of hydrogen-atoms is 12 ($=2\cdot5+2$), and we have thus the representations of three different paraffines, C_5H_{12}. It should be observed that the tree-symbol of the paraffine is completely determined by means of the tree formed with the carbon-atoms, or say of the carbon-tree, and that the question of the determination of the theoretic number of the paraffines C_nH_{2n+2} is consequently that of the determination of the number of the carbon-trees of n knots, viz. the number of trees with n knots, subject to the condition that the number of branches from each knot is at most $=4$.

In the paper of 1857 (which contains no application to chemical theory) the number of branches from a knot was unlimited; and moreover the trees were considered as issuing each from one knot taken as a root, so that, $n=5$, the trees regarded as distinct (instead of being as above only 3) were in all 9, viz. these were



which, regarded as issuing from the bottom knots, are in fact distinct; while taking them as issuing each from a properly selected knot, they resolve themselves into the above-mentioned 3 forms. The problem considered was in fact that of the "general root-trees with n knots"—*general*, inasmuch as the number of branches from a knot was without limit; *root-trees*, inasmuch as the enumeration was made on the principle last referred to. It was found that for

knots	1	2	3	4	5	6	7	8	....
No. of trees was..	1	1	2	4	9	20	48	115	....
=	1	A_1	A_2	A_3	A_4	A_5	A_6	A_7	....

the law being given by the equation

$$(1-x)^{-1}(1-x^2)^{-A_1}(1-x^3)^{-A_2}(1-x^4)^{-A_3}\dots$$
$$=1+A_1x+A_2x^2+A_3x^3+A_4x^4+\dots;$$

but the next following numbers A_8, A_9, A_{10}, the correct values of which are 286, 719, 1842, were given erroneously as 306, 775, 2009. I have since calculated two more terms, A_{11}, $A_{12}=4766$, 12486.

The other questions considered in the paper of 1857 and in that of 1860 have less immediate connexion with the present paper, but for completeness I reproduce the results in a Note*.

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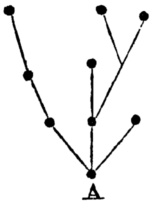
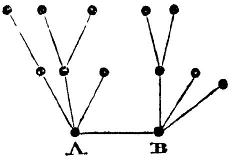
* In the paper of 1857 I also considered the problem of finding B_r the number with r free branches, bifurcations at least: this was given by a like formula—

To count the trees on the principle first referred to, we require the notions of "centre" and "bicentre," due, I believe, to Sylvester; and to establish these we require the notions of "main branch" and "altitude": viz. in a tree, selecting any knot at pleasure as a root, the branches which issue from the root, each with all the branches that belong to it, are the main branches, and the distance of the furthest knot, measured by the number of intermediate branches, is the altitude of the main branch. Thus in the left-hand figure, taking A as the root, there are 3 main branches of the altitudes 3, 3, 1 respectively: in the right-hand figure, taking A as the root, there are 4 main branches of the altitudes 2, 2, 1, 3 respectively; and we have then the theorem that in every tree there is either one and only one centre, or else one and only one bicentre; viz. we have (as in the left-hand figure) a centre A which is such that there issue from it two or more main branches of alti-





$$(1-x)^{-1}(1-x^2)^{-B_2}(1-x^3)^{-B_3}(1-x^4)^{-B_4}\ .\ =1+x+2B_2x^2+2B_3x^3+2B_4x^4\ldots,$$

leading to

$$\begin{array}{rcccccc} B_r= & 1, & 2, & 5, & 12, & 33, & 90,\ldots. \\ \text{for } r= & 2, & 3, & 4, & 5. & 6, & 7,\ldots. \end{array}$$

In the paper of 1860, the question is to find the number of trees with a given number m of terminal knots we have here

$$\phi m=1.2.3\ldots(m-1) \text{ coefficient } x^{m-1} \text{ in } \frac{1}{2-e^x},$$

giving the values

$$\begin{array}{rcccccccc} \phi m= & 1, & 1, & 3, & 13, & 75, & 541, & 4683, & 47293,\ldots. \\ \text{for } m= & 1, & 2, & 3, & 4, & 5, & 6, & 7, & 8,\ \ldots. \end{array}$$

But if from each non-terminal knot there ascend two and only two branches, then in this case $\phi m=$ coefficient x^{m-1} in $\frac{1-\sqrt{1-4x}}{2x}$ viz. we have the very simple form

$$\phi m=\frac{1.3.5\ldots 2m-3}{1.2.3\ldots m}2^{m-1},$$

$$\begin{array}{lrcccccc} \text{giving} & \phi m= & 1, & 1, & 2, & 5, & 14, & 42,\ldots. \\ \text{for} & m= & 1, & 2, & 3, & 4, & 5, & 7,\ldots. \end{array}$$

tudes equal to each other and superior to those of the other main branches (if any); or else (as in the right-hand figure) a bicentre AB, viz. two contiguous knots, such that issuing from A (but not counting AB), and issuing from B (but not counting BA), we have two or more main branches, one at least from A and one at least from B, of altitudes equal to each other and superior to those of the other main branches in question (if any). The theorem once understood, is proved without difficulty: we consider two terminal knots, the distance of which, measured by the number of intermediate branches, is greater than or equal to that of any other two terminal knots; if, as in the left-hand figure, the distance is even, then the central knot A is the centre of the tree; if, as in the right-hand figure, the distance is odd, then the two central knots AB form the bicentre of the tree.

In the former case, observe that if G, H are the two terminal knots, the distance of which is $=2\lambda$, then the distance of each from A is $=\lambda$, and there cannot be any other terminal knot I, the distance of which from A is greater than λ (for if there were, then the distance of I from G or else from H would be greater than 2λ); there cannot be any two terminal knots I, J, the distance of which is greater than 2λ; and if there are any two knots I, J, the distance of which is $=2\lambda$, then these belong to different main branches, the distance of each of them from A being $=\lambda$; whence, starting with I, J (instead of G, H), we obtain the same point A as centre. Similarly in the latter case there is a single bicentre AB.

Hence, since in any tree there is a unique centre or bicentre, the question of finding the number of distinct trees with n knots is in fact that of finding the number of centre- and bicentre-trees with n knots; or say it is the problem of the "general centre- and bicentre-trees with n knots:" *general*, inasmuch as the number of branches from a knot is as yet taken to be without limit; or since (as will appear) the number of the bicentre-trees can be obtained without difficulty when the problem of the root-trees is solved, the problem is that of the "general centre-trees with n knots." It will appear that the solution depends upon and is very readily derived from that of the foregoing problem of general root-trees, so that this last has to be considered, not only for its own sake, but with a view to that of the centre-trees. And in each of the two problems we doubly divide the whole system of trees according to the number of the main branches (issuing from the root or centre as the case may be), and according to the altitude of the longest main branch or branches, or say the altitude of the tree; so that the problem really is, for a given number of knots, a given number of main branches, and a given altitude, to find the number of root-trees, or (as the case may be) centre-trees.

We next introduce the restriction that the number of branches from any knot is equal to a given number at most; viz. according as this number is $=2$, 3 or 4, we have, say oxygen-trees, boron-trees*, and carbon-trees respectively; and these are as before root-trees or centre- or bicentre-trees, as the case may be. The case where the number is 2 presents no difficulty: in fact if the number of knots be $=n$, then the number of root-trees is either $\frac{1}{2}(n+1)$ or $\frac{1}{2}n$; viz. $n=3$ and $n=4$, the root-trees are

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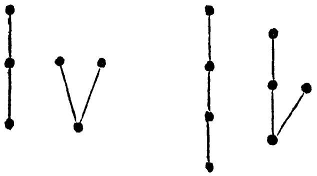
* I should have said nitrogen-trees; but it appears to me that nitrogen is of necessity 5-valent, as shown by the compound, Ammonium-Chloride, $=NH_4Cl$: of course the word boron is used simply to stand for a 3-valent element



and the number of centre- or bicentre-trees is always$=1$: viz. n odd, there is one centre-tree; and n even, one bicentre-tree; it is only considered as a particular case of the general theorem. The case where the number is $=3$ is analytically interesting: although there may not exist, for any 3-valent element, a series of hydrogen compounds $B_n\,H_{n+2}$ corresponding to the paraffines. The case where the number is $=4$, or say the carbon-trees, is that which presents the chief chemical interest, as giving the paraffines $C_n\,H_{2n+2}$; and I call to mind here that the theory of the carbon-root trees is established as an analytical result for its own sake and as the foundation for the other case, but that it is the number of the carbon centre- and bicentre-trees which is the number of the paraffines.

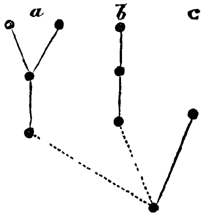
The theory extends to the case where the number of branches from a knot is at most $=5$, or $=$ any larger number; but I have not developed the formula.

I pass now to the analytical theory: considering first the case of general root-trees, we endeavour to find for a given altitude N the number of trees of a given number of knots n and main branches α, or say the generating function

$$\Sigma\Omega t^{\alpha}x^{n},$$

where the coefficient Ω gives the number of the trees in question. And we assume that the problem is solved for the cases of the several inferior altitudes $0, 1, 2, 3 \ldots N-1$.

This being so, observe that a tree of altitude N can be built up as shown



in the figure (which I call the edification diagram), by combining one or more trees of altitude $N-1$ with a single tree of altitude not exceeding $N-1$; viz. in the figure, $N=3$, we have the two trees a, b, each of altitude 2, combined (as shown by the dotted lines) with the tree c of altitude 1: the whole number of knots in the resulting tree is the sum of the number of knots on the three trees a, b, c: the number of main branches is equal to the number of the trees a, b, plus the number of main branches of the tree c. It is to be observed that the tree c may reduce itself to the tree (.) of one knot and of altitude zero; but each of the trees a, b, as being of the altitude $N-1$, must contain at least N knots.

Taking $N=2$ or any larger number, it is hence easy to see that the required generating function $\Sigma\Omega t^a x^n$ is

$$=(1-tx^{N})^{-1}(1-tx^{N+1})^{-l_1}(1-tx^{N+2})^{-l_2}\ldots[t^{1\cdot\cdot\infty}] \quad \text{(first factor)},$$

$$x+(t)x^2+(t,t^2)x^3+(t,t^2,t^3)x^4+\ldots \qquad \text{(second factor)},$$

where, as regards the first factor, the exponents taken with reversed sign, that is as positive, are $1=$ no. of trees, altitude $N-1$, of N knots; $l_1=$ ditto, same altitude, of $(N+1)$ knots; $l_2=$ ditto, same altitude, of $N+2$ knots, and so on; and where the symbol $[t^{1\cdot\cdot\infty}]$ denotes that in the function or product of factors which precedes it, the terms to be taken account of are those in $t^1, t^2, t^3\ldots$; viz. that the term in t^0, or constant term ($=1$ in fact), is to be rejected.

In the second factor the expressions $x, (t)x^2, (t,t^2)x^3, \ldots$ represent (for given exponents of t, x, denoting the number of main branches and the number of knots respectively) the number of trees of altitude not exceeding $N-1$: thus $x, =1\,t^0x^1$ represents the number of such trees, 1 knot, 0 main branch, $=1$; and so if the value of $(t,t^2,t^3,t^4)x^5$ be $(\alpha t+\beta t^2+\gamma t^3+\delta t^4)x^5$, then for trees of an altitude not exceeding $N-1$, and of 5 knots, α represents the number of trees of 1 main branch, β that of trees of 2 main branches, γ that of trees of 3 main branches, δ that of trees of 4 main branches. It is clear that the number of trees satisfying the given conditions and of an altitude not exceeding $N-1$ is at once obtained by addition of the numbers of the trees satisfying the given conditions, and of the altitudes $0, 1, 2\ldots N-1$; all which numbers are taken to be known.

It is to be remarked that the first factor,

$$(1-tx^{N})^{-1}(1-tx^{N+1})^{-l_1}(1-tx^{N+2})^{-l_2}\ldots[t^{1\cdot\infty}],$$

shows by its development the number of combinations of trees a, b.. of the altitude $N-1$; one such tree at least *must* be taken, and the symbol $[t^{1\cdot\infty}]$ gives effect to this condition: the second factor $x+(t)x^2+(t,t^2)x^3+\ldots$ shows the number of the trees c of altitude not exceeding $N-1$. And this being so, there is no difficulty in seeing how the product of the two factors is the generating function for the trees of altitude N.

In the case $N=0$, the generating function, or GF, is $=x$; viz. altitude 0, there is only the tree (.) 1 knot, 0 main branch.

$$N=1,\ \text{the GF is}=(1-tx)^{-1}[t^{1\cdot\infty}]x,\ =tx^2+t^2x^3+t^3x^4\ldots,$$

viz. altitude 1, there is 1 tree tx^2, 2 knots, 1 main branch; 1 tree t^2x^3, 3 knots, 2 main branches; and so on.

Hence $N=2$, we obtain

$$\text{GF}=(1-tx^2)^{-1}(1-tx^3)^{-1}(1-tx^4)^{-1}\ldots[t^{1\cdots\infty}].(x+tx^2+t^2x^3+t^3x^4\ldots.);$$

viz. as regards the second factor, altitude not exceeding 1, that is $=0$ or 1, there is altitude 0, 1 tree x, and altitude 1, 1 tree tx^2, 1 tree t^2x^3, and so on. And we hence derive the GF's for the higher values $N=3, 4$, &c.: the details of the process will be afterwards more fully explained.

So far we have considered root-trees; but referring to the last diagram, it is at once seen that the assumed root will be a centre, provided only that (instead of, it may be, only a single tree a of the altitude $\mathrm{N}-1$), we take always two or more trees of the altitude $\mathrm{N}-1$ to form the new tree of the altitude N. And we give effect to this condition by simply writing in place of $[t^{1\cdots\infty}]$ the new symbol $[t^{2\cdots\infty}]$, which denotes that only the terms $t^2, t^3, t^4\ldots$ are to be taken account of; viz. that the terms in t^0 and t^1 are to be rejected. The component trees of the altitude $\mathrm{N}-1$ are, it is to be observed, as before, root-trees; hence the second factor of the generating function is unaltered: the theorem is that for the centre-trees of altitude N we have the same generating function as for the root-trees, writing only $[t^{2\cdots\infty}]$ in place of $[t^{1\cdots\infty}]$. Or, what is the same thing, supposing that the first factor, unaffected by either symbol, is

$$=1+x^{\mathrm{N}}(\alpha t+\beta t^2+\ldots)+x^{\mathrm{N}+1}(\alpha' t+\beta' t^2+\ldots)+\ldots,$$

then affecting it with $[t^{1\cdots\infty}]$ the value for the root-trees is

$$=x^{\mathrm{N}}(\alpha t+\beta t^2+\ldots)+x^{\mathrm{N}+1}(\alpha' t+\beta' t^2+\ldots)+\ldots,$$

and affecting it with $[t^{2\cdots\infty}]$ the value for the centre-trees is

$$=x^{\mathrm{N}}(\beta t^2+\ldots)+x^{\mathrm{N}+1}(\beta' t^2+\ldots)+\ldots$$

It thus appears how the fundamental problem is that of the root-trees, its solution giving at once that of the centre-trees; whereas we cannot conversely solve the problem of the root-trees by means of that of the centre-trees.

As regards the bicentre-trees, it is to be remarked that starting from a centre-tree of altitude $\mathrm{N}+1$ with two main branches, then by simply striking out the centre, so as to convert into a single branch the two branches which issue from it, we obtain a bicentre-tree of altitude N. Observe that the altitude of a bicentre-tree is measured by that of the longest main branch from A or B, not reckoning AB or BA as a main branch. Hence the number of bicentre-trees, altitude N, is = number of centre-trees of two main branches, altitude $\mathrm{N}+1$.

This is in fact the convenient formula, provided only the number of centre-trees of two main branches has been calculated up to the altitude $\mathrm{N}+1$; but we can find independently the number of bicentre-trees of a given altitude N: the bicentre-tree is in fact formed by taking the two connected points A, B each as the root of a root-tree altitude N (the number of knots of the bicentre-tree being thus, it is clear, equal to the sum of the numbers of knots of the two root-trees respectively); and it is thus an easy problem of combinations to find the number of bicentre-trees of a given altitude N. Write

$$x^{\mathrm{N}+1}(1+\beta x+\gamma x^2+\delta x^3+\ldots)$$

as the generating function of the root-trees of altitude N; viz. for such trees, 1=no. of trees with $\mathrm{N}+1$ knots, β=no. with $\mathrm{N}+2$ knots, and so on; then the generating function of the bicentre-trees of the same altitude N is

$$=x^{2\mathrm{N}+2}(1+\beta_{,}x+\gamma_{,}x^2+\delta_{,}x^3+\ldots),$$

where
$$\beta_{,}=\beta,$$
$$\gamma_{,}=\gamma+\tfrac{1}{2}\beta(\beta+1),$$
$$\delta_{,}=\delta+\beta\gamma,$$
$$\epsilon_{,}=\epsilon+\beta\delta+\tfrac{1}{2}\gamma(\gamma+1),$$
$$\zeta_{,}=\zeta+\beta\epsilon+\gamma\delta,$$

and so on; or, what is the same thing, calling the first generating function ϕx, then the second generating function is $=\frac{1}{2}\{(\phi x)^2+\phi(x^2)\}$.

It will be noticed that the bicentre-trees are not (as were the centre-trees) divided according to the number of their main branches; they might be thus divided according to the sum of the number of the main branches issuing from the two points of the bicentre respectively; a more complete division would be according to the number of main branches issuing from the two points respectively; thus we might consider the bicentre-trees (2, 3) with 2 main branches from one point, and 3 main branches from the other point of the bicentre; but the whole theory of the bicentre-trees is comparatively easy, and I do not go into it further.

We have yet to consider the case of the limited trees where the number of branches from a knot is equal to a given number at most: to fix the ideas, say the carbon-trees, where this number is $=4$. The distinction as to root-trees and centre- and bicentre-trees is as before, and the like theory applies to the two cases respectively. Considering first the case of the root-trees, and referring to the former figure for obtaining the trees of altitude N from those of inferior altitudes, then the trees $a, b\ldots$ of altitude $N-1$ must be each of them a carbon-tree of not more than $(4-1=)3$ main branches: this restriction is necessary, inasmuch as if for any such tree the number of main branches was $=4$, then there would be from the root of such tree 4 branches *plus* the new branch shown by the dotted line, in all 5 branches; and similarly, inasmuch as there is at least one component tree a contributing one main branch, the number of main branches of the tree c must be $(4-1=)3$ at most: the mode of introducing these conditions will appear in the explanation of the actual formation of the generating functions [see explanation preceding Tables III., IV., &c.]. The number of main branches is $=4$ at most, and the generating functions have only to be taken up to the terms in t^4; the first factor is consequently in each case affected with a symbol $[t^{1\cdots4}]$, denoting that the only terms to be taken account of are those in t, t^2, t^3, t^4; hence as there is a factor t at least, and the whole is required only up to t^4, the second factor is in each case required only up to t^3.

As regards the centre-trees, the generating functions have here the same expressions as for the root-trees, except that instead of the symbol $[t^{1\cdots4}]$, we have the symbol $[t^{2\cdots4}]$, denoting that in the first factor the only terms to be taken account of are those in t^2, t^3, t^4; hence as there is a factor t^2 at least, and the whole is required only up to t^4, the second factor is in each case required up to t^2; and we then complete the theory by obtaining the bicentre-trees. The like remarks apply of course to the boron-trees, number of branches $=3$ at most, and to the oxygen-trees, number $=2$ at most; but, as already remarked, this last case is so simple, that the general method is applied to it only for the sake of seeing what the general method becomes in such an extreme case.

We thus form the Tables, which I proceed to explain.

Table I. of general root-trees is in fact a Table of triple entry, viz. it gives for any given number of knots from 1 to 13 the number of root-trees corresponding to any given number of main branches and to any given altitude. In each compartment, that is for any given number of knots, the totals of the columns give the number of the trees for each given altitude, and the totals of the lines give the number of the trees for each given number of main branches: the corner grand totals of these totals respectively show for each given number of knots the whole number of root-trees:—

viz. knots....	1	2	3	4	5	6	7	8	9	10	11	12	13
numbers are..	1	1	2	4	9	20	48	115	286	719	1842	4766	12486

as already mentioned, and which numbers were calculated by an independent method.

Table II. of general centre- and bicentre-trees consists of a centre part and a bicentre part: the centre part is arranged precisely in the same manner as the root-table. As to the bicentre part, where it will be observed there is no division for number of main branches, the calculation of the several columns is effected by the before-mentioned formula,

$$\phi_{,}x=\tfrac{1}{2}\{(\phi x)^2+\phi(x^2)\}\ ;$$

thus column 2, we have by Table I. (totals of column 2)

$$\phi x=x^3+2x^4+4x^5+6x^6+10x^7+14x^8+21x^9+29x^{10}+\ldots,$$

and thence

$$\phi_{,}x=x^6+2x^7+7x^8+14x^9+32x^{10}+58x^{11}+110x^{12}+187x^{13}+\ldots$$

As already mentioned, Table I. is calculated each column by means of a generating function given as a product of two factors, each of which is obtained from the columns which precede the column in question; and Table II., the centre part of it, is calculated by means of the same generating functions slightly modified: these generating functions serving for the calculation of the two Tables are given in the table entitled "Subsidiary Table for the calculation of the GF's of Tables I. and II.," which immediately follows these two Tables, and will be further explained.

TABLE I.—General Root-trees.

Index *x*, or number of knots.	Index *t*, or number of main branches.	Altitude or number of column.													
		0	1	2	3	4	5	6	7	8	9	10	11	12	13
1	0	1	1												
	Total	1	**1**												
2	1		1	1											
	Total		1	**1**											
3	1			1	1										
	2		1		1										
	Total		1	1	**2**										
4	1			1	1	1									
	2			1		2									
	3		1			1									
	Total		1	2	1	**4**									
5	1			1	2	1	4								
	2			2	1		3								
	3			1			1								
	4		1				1								
	Total		1	4	3	1	**9**								

6	1			1	4	3	1	9						
	2			2	3	1		6						
	3			2	1			3						
	4			1				1						
	5		1					1						
	Total		1	6	8	4	1	**20**						
7	1			1	6	8	4	1	20					
	2			3	8	4	1		16					
	3			3	3	1			7					
	4			2	1				3					
	5			1					1					
	6		1						1					
	Total		1	10	18	13	5	1	**48**					
8	1			1	10	18	13	5	1	48				
	2			3	15	13	5	1		37				
	3			4	9	4	1			18				
	4			3	3	1				7				
	5			2	1					3				
	6			1						1				
	7		1							1				
	Total		1	14	38	36	19	6	1	**115**				
9	1			1	14	38	36	19	6	1	115			
	2			4	30	36	19	6	1		96			
	3			5	19	14	5	1			44			
	4			5	9	4	1				19			
	5			3	3	1					7			
	6			2	1						3			
	7			1							1			
	8		1								1			
	Total		1	21	76	93	61	26	7	1	**286**			

Table I. (*continued*).

Index x, or number of knots.	Index t, or number of main branches.	Altitude or number of column.													
		0	1	2	3	4	5	6	7	8	9	10	11	12	13
10	1			1	21	76	93	61	26	7	1	286			
	2			4	51	89	61	26	7	1		239			
	3			7	42	41	20	6	1			117			
	4			6	20	14	5	1				46			
	5			5	9	4	1					19			
	6			3	3	1						7			
	7			2	1							3			
	8			1								1			
	9		1									1			
	Total		1	29	147	225	180	94	34	8	1	**719**			
11	1			1	29	147	225	180	94	34	8	1	719		
	2			5	90	210	180	94	34	8	1		622		
	3			8	79	110	67	27	7	1			299		
	4			9	46	42	20	6	1				124		
	5			7	20	14	5	1					47		
	6			5	9	4	1						19		
	7			3	3	1							7		
	8			2	1								3		
	9			1									1		
	10		1										1		
	Total		1	41	277	528	498	308	136	43	9	1	**1842**		

12	1			1	41	277	528	498	308	136	43	9	1	1842	
	2			5	145	467	493	308	136	43	9	1		1607	
	3			10	152	278	208	101	35	8	1			793	
	4			11	91	115	68	27	7	1				320	
	5			10	47	42	20	6	1					126	
	6			7	20	14	5	1						47	
	7			5	9	4	1							19	
	8			3	3	1								7	
	9			2	1									3	
	10			1										1	
	11		1											1	
	Total		1	55	509	1198	1323	941	487	188	53	10	1	**4766**	
13	1			1	55	509	1198	1323	941	487	188	53	10	1	4766
	2			6	238	1012	1524	941	487	188	53	10	1		4460
	3			12	272	669	376	344	144	44	9	1			1871
	4			15	184	299	213	102	35	8	1				857
	5			13	95	116	68	27	7	1					327
	6			11	47	42	20	6	1						127
	7			7	20	14	5	1							47
	8			5	9	4	1								19
	9			3	3	1									7
	10			2	1										3
	11			1											1
	12		1												1
	Total		1	76	924	2666	3405	2744	1615	728	251	64	11	1	**12486**

TABLE II.—General Centre- and Bicentre-Trees.

Index x, or number of knots.	Index t, or number of main branches.	Centre-Trees. Altitude or number of column.								Centre.	Grand Total.	Bicentre.	Bicentre-Trees. Altitude.					
		0	1	2	3	4	5	6					0	1	2	3	4	5
1	0	1	1							1	1	0						
	Total	1	**1**															
2										0	1	1	1					
3	2		1	1														
	Total		1	**1**						1	1	0						
4	2																	
	3		1	1														
	Total		1	**1**						1	2	1		1				
5	2			1	1													
	3																	
	4		1		1													
	Total		1	1	**2**					2	3	1		1				

6	2			1	1													
	3			1	1													
	4																	
	5		1		1													
	Total		1	2	**3**					3	6	3		2	1			
7	2			2	1	3												
	3			2		2												
	4			1		1												
	5																	
	6		1			1												
	Total		1	5	1	**7**				7	11	4		2	2			
8	2			2	2	4												
	3			3	1	4												
	4			2		2												
	5			1		1												
	6																	
	7		1			1												
	Total		1	8	3	**12**				12	23	11		3	7	1		
9	2			3	7	1	11											
	3			4	3		7											
	4			4	1		5											
	5			2			2											
	6			1			1											
	7																	
	8		1				1											
	Total		1	14	11	1	**27**			27	47	20		3	14	3		

Table II. (*continued*).

Index x, or number of knots.	Index t, or number of main branches.	Centre-Trees. Altitude or number of column.								Centre.	Grand Total.	Bicentre.	Bicentre-Trees. Altitude.					
		0	1	2	3	4	5	6					0	1	2	3	4	5
10	2			3	14	3	20											
	3			6	11	1	18											
	4			5	3		8											
	5			4	1		5											
	6			2			2											
	7			1			1											
	8																	
	9		1				1											
	Total		1	21	29	4	**55**			55	106	51		4	32	14	1	
11	2			4	32	14	1	51										
	3			7	26	4		37										
	4			8	12	1		21										
	5			6	3			9										
	6			4	1			5										
	7			2				2										
	8			1				1										
	9																	
	10		1					1										
	Total		1	32	74	19	1	**127**		127	235	108		4	58	42	4	

12	2			4	58	42	4	108									
	3			9	63	19	1	92									
	4			10	30	4		44									
	5			9	12	1		22									
	6			6	3			9									
	7			4	1			5									
	8			2				2									
	9			1				1									
	10																
	11		1					1									
	Total		1	45	167	66	5	**284**		284	551	267		5	110	128	23	1
13	2			5	110	128	23	1	267								
	3			11	132	66	5		214								
	4			14	78	20	1		113								
	5			12	31	4			47								
	6			10	12	1			23								
	7			6	3				9								
	8			4	1				5								
	9			2					2								
	10			1					1								
	11																
	12		1						1								
	Total		1	65	367	219	29	1	**682**	682	1301	619		5	187	334	88	5

Subsidiary Table for GF's of Tables I. and II.

Index *i*.	Index of *x*.														
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	
0		1													GF, column 0.
*		−1													GF, column 1.
0	(1)														First factor.
1		1													
2			1												
3				1											
4					1										
5						1									
6							1								
7								1							
8									1						
9										1					
10											1				
11												1			
12													1		
0		1													Second factor.
*			−1	−1	−1	−1	−1	−1	−1	−1	−1	−1	−1		GF, column 2.
0	(1)														First factor.
1			1	1	1	1	1	1	1	1	1	1	1		
2					1	1	2	2	3	3	4	4	5		
3							1	1	2	3	4	5	7		
4									1	1	2	3	5		
5											1	1	2		
6													1		

0		1													Second factor.
1			1												
2				1											
3					1										
4						1									
5							1								
6								1							
7									1						
8										1					
9											1				
10												1			
11													1		
12														1	
*				−1	−2	−4	−6	−10	−14	−21	−29	−41	−55	−76	GF, column 3.
0	(1)														First factor.
1		.	.	1	2	4	6	10	14	21	29	41	55		
2							1	2	7	14	32	58	110		
3										1	2	7	18		
4													1		
0		1													Second factor.
1			1	1	1	1	1	1	1	1	1	1	1	1	
2				1	1	2	2	3	3	4	4	5	5	6	
3					1	1	2	3	4	5	7	8	10	12	
4						1	1	2	3	5	6	9	11	15	
5							1	1	2	3	5	7	10	13	
6								1	1	2	3	5	7	11	
7									1	1	2	3	5	7	
8										1	1	2	3	5	
9											1	1	2	3	
10												1	1	2	
11													1	1	
12														1	

Subsidiary Table for GF's of Tables I. and II. (*continued*).

Index *t*.	Index of *x*.														
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	
*					−1	−3	−8	−18	−38	−76	−147	−277	−509	−924	GF, column 4.
0	(1)														First factor.
1				·	1	3	8	18	38	76	147	277	509		
2									1	3	14	42	128		
3													1		
0		1													Second factor.
1			1	1	2	3	5	7	11	15	22	30	42	56	
2				1	1	3	5	11	18	34	55	95	150	244	
3					1	1	3	6	13	24	49	87	162	284	
4						1	1	3	6	14	26	55	102	199	
5							1	1	3	6	14	27	57	108	
6								1	1	3	6	14	27	58	
7									1	1	3	6	14	27	
8										1	1	3	6	14	
9											1	1	3	6	
10												1	1	3	
11													1	1	
12														1	
*	·				·	−1	−4	−13	−36	−93	−255	−528	−1198	−2666	GF, column 5.
0	(1)														First factor.
1						1	4	13	36	93	225	528	1198		
2											1	4	23		

0		1													Second factor.
1			1	1	2	4	8	15	29	53	98	177	319	565	
2				1	1	3	6	15	31	70	144	305	617	1256	
3					1	1	3	7	17	38	90	197	440	953	
4						1	1	3	7	18	40	97	217	498	
5							1	1	3	7	18	41	99	224	
6								1	1	3	7	18	41	100	
7									1	1	3	7	18	41	
8										1	1	3	7	18	
9											1	1	3	7	
10												1	1	3	
11													1	1	
12														1	
*	·	·	·	·	·	·	−1	−5	−19	−61	−180	−498	−1323	−3405	GF, column 6.
0	(1)														First factor
1							1	5	19	61	180	498	1323		
2													1		
0		1													Second factor.
1			1	1	2	4	9	19	42	89	191	402	847	1763	
2				1	1	3	6	16	36	89	205	485	1110	2780	
3					1	1	3	7	18	43	110	264	648	1329	
4						1	1	3	7	19	45	117	285	711	
5							1	1	3	7	19	46	119	292	
6								1	1	3	7	19	46	120	
7									1	1	3	7	19	46	
8										1	1	3	7	19	
9											1	1	3	7	
10												1	1	3	
11													1	1	
12														1	

Subsidiary Table for GF's of Tables I. and II. (*continued*).

Index *t*.	Index of *x*.														
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	
*								−1	−6	−26	−94	−308	−941	−2744	GF, column 7.
0	(1)														First factor.
1								1	6	26	94	308	941		
0		1													Second factor.
1			1	1	2	4	9	20	47	108	252	582	1345	3086	
2				1	1	3	6	16	37	95	231	579	1418	3721	
3					1	1	3	7	18	44	116	291	749	1673	
4						1	1	3	7	19	46	123	312	813	
5							1	1	3	7	19	47	125	319	
6								1	1	3	7	19	47	126	
7									1	1	3	7	19	47	
8										1	1	3	7	19	
9											1	1	3	7	
10												1	1	3	
11													1	1	
12														1	

*									−1	−7	−34	−136	−487	−1615	GF, column 8.
0	(1)														First factor.
1									1	7	34	136	487	1615	
0		1													Second factor.
1			1	1	2	4	9	20	48	114	278	676	1653	4027	
2				1	1	3	6	16	37	96	238	613	1554	4208	
3					1	1	3	7	18	44	117	298	784	1817	
4						1	1	3	7	19	46	124	319	848	
5							1	1	3	7	19	47	126	326	
6								1	1	3	7	19	47	127	
7									1	1	3	7	19	47	
8										1	1	3	7	19	
9											1	1	3	7	
10												1	1	3	
11													1	1	
12														1	
*										−1	−8	−43	−188	−728	GF, column 9.
0	(1)														First factor.
1										1	8	43	188	728	
0		1													Second factor.
1			1	1	2	4	9	20	48	115	285	710	1789	4514	
2				1	1	3	6	16	37	96	239	621	1597	4396	
3					1	1	3	7	18	44	117	299	792	1861	
4						1	1	3	7	19	46	124	320	856	
5							1	1	3	7	19	47	126	327	
6								1	1	3	7	19	47	127	
7									1	1	3	7	19	47	
8										1	1	3	7	19	
9											1	1	3	7	
10												1	1	3	
11													1	1	
12														1	

Subsidiary Table for GF's of Tables I. and II. (*continued*).

Index *t*.	Index of *x*.														
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	
*											−1	−9	−53	−251	GF, column 10.
0	(1)														First factor.
1											1	9	53	251	
0		1													Second factor.
1			1	1	2	4	9	28	48	115	286	718	1832	4702	
2				1	1	3	6	16	37	96	239	622	1606	4449	
3					1	1	3	7	18	44	117	299	793	1870	
4						1	1	3	7	19	46	124	320	857	
5							1	1	3	7	19	47	126	327	
6								1	1	3	7	19	47	127	
7									1	1	3	7	19	47	
8										1	1	3	7	19	
9											1	1	3	7	
10												1	1	3	
11													1	1	
12														1	
*												−1	−10	−64	GF, column 11.
0	(1)														First factor.
1												1	10	64	
0		1													Second factor.
1			1	1	2	4	9	20	48	115	286	719	1841	4755	
2				1	1	3	6	16	37	96	239	622	1607	4459	
3					1	1	3	7	18	44	117	299	793	1871	
4						1	1	3	7	19	46	124	320	857	
5							1	1	3	7	19	47	126	327	
6								1	1	3	7	19	47	127	
7									1	1	3	7	19	47	
8										1	1	3	7	19	
9											1	1	3	7	
10												1	1	3	
11													1	1	
12														1	

*													−1	−11	.GF, column 12.
0	(1)														First factor.
1													1	11	
0		1													Second factor.
1			1	1	2	4	9	20	48	115	286	719	1842	4765	
2				1	1	3	6	16	37	90	239	622	1607	4460	
3					1	1	3	7	18	44	117	299	793	1871	
4						1	1	3	7	19	46	124	320	857	
5							1	1	3	7	19	47	126	327	
6								1	1	3	7	19	47	127	
7									1	1	3	7	19	47	
8										1	1	3	7	19	
9											1	1	3	7	
10												1	1	3	
11													1	1	
12														1	

*														−1	GF, column 13.
0	(1)														First factor.
1														1	
0		1													Second factor.
1			1	1	2	4	9	20	48	115	286	719	1842	4766	
2				1	1	3	6	16	37	96	239	622	1607	4460	
3					1	1	3	7	18	44	117	299	793	1871	
4						1	1	3	7	19	46	124	320	857	
5							1	1	3	7	19	47	126	327	
6								1	1	3	7	19	47	127	
7									1	1	3	7	19	47	
8										1	1	3	7	19	
9											1	1	3	7	
10												1	1	3	
11													1	1	
12														1	

I proceed to explain the Subsidiary Table, first in its application to Table I.

The Subsidiary Table is divided into sections, giving the GF's of the successive columns of Table I., each section being given by means of the preceding columns of Table I.; for instance, that for column 3 by means of columns 0, 1, 2 of Table I.

As regards column 0, the Table shows that the GF is $=x$.

As regards column 1, that the GF has a first factor,

$$(1-tx)^{-1}, =(1)+tx+t^2x^2+t^3x^3+\ldots,$$

which is operated on by the symbol $[t^{1\cdot\cdot\infty}]$, viz. the constant term (1) is to be rejected; and that it has a second factor, $=x$: the product of these, viz. $(tx+t^2x^2+t^3x^3\ldots)\times x$, is the required GF, the coefficients of which are accordingly given in column 1 of Table I.

As regards column 2, it shows that the GF has a first factor,

$$(1-tx^2)^{-1}(1-tx^3)^{-1}(1-tx^4)^{-1}\ldots.,$$

where the indices $-1, -1, -1\ldots$ are the sums of the numbers in column 1, Table I., which first factor is

$$1+tx^2+tx^3\,.+\begin{pmatrix} t \\ +t^2 \end{pmatrix}x^4+\ldots$$

(and it is as before to be operated on with $[t^{1\cdot\cdot\infty}]$, viz. the constant term is to be rejected); and further, that there is a second factor $=x+tx^2+t^2x^3+\ldots$, the coefficients of which are obtained by summation of the numbers in the several lines of columns 0, 1 of Table I. We have thence column 2 of Table I.

As regards column 3, it shows that the GF has a first factor,

$$(1-tx^3)^{-1}(1-tx^4)^{-2}(1-tx^5)^{-4}\ldots.,$$

where the indices $-1, -2, -4\,..$ are the sums of the numbers in column 2 of Table I., which first factor is

$$=1+tx^3+2tx^4+4tx^5+\begin{pmatrix} 6t \\ +t^2 \end{pmatrix}x^6+\ldots$$

(and it is as before to be operated on with $[t^{1\cdot\cdot\infty}]$, viz. the constant term is to be rejected); and that there is a second factor

$$=x+tx^2+\begin{pmatrix} t \\ +t^2 \end{pmatrix}x^3+\begin{pmatrix} t \\ +t^2 \\ +t^3 \end{pmatrix}x^4+\ldots,$$

the coefficients of which are obtained by summation of the numbers in the several lines of columns 0, 1, 2 of Table I.: we have thence column 3 of Table I.

And similarly, by means of columns 0, 1, 2, 3 of Table I., we form the GF of column 4; that is, we obtain column 4 of Table I., and so on indefinitely.

To apply the Subsidiary Table to the calculation of the GF's of Table II., the only difference is that the first factors are to be taken without the terms in t^1: thus for Table II. column 3, the first factor of the GF

$$=t^2x^6+2t^2x^7+7t^2x^8+\begin{pmatrix}14t^2\\+t^3\end{pmatrix}x^9+\&c.,$$

the second factor being as for Table I.

$$=x+tx^2+\begin{pmatrix}t\\+t^2\end{pmatrix}x^3+\&c.$$

The remaining Tables are Tables III. and IV., oxygen root-trees and centre- and bicentre-trees, followed by a Subsidiary Table for the calculation of the GF's: Tables V. and VI., boron root-trees and centre- and bicentre-trees, followed by a Subsidiary Table; and Tables VII. and VIII., carbon root-trees and centre- and bicentre-trees, followed by a Subsidiary Table. The explanations given as to Tables I., II. and the Subsidiary Table apply *mutatis mutandis* to these; and but little further explanation is required: that given in regard to the Subsidiary Table of Tables III. and IV. shows how this limiting case comes under the general method. As to the Subsidiary of Tables V. and VI., it is to be observed that each* line of the Table is calculated from a column of Table V., rejecting the numbers which belong to t^3; thus Table V., column 4, the numbers are

t^1	1	3	5	7	8	9 ...
t^2		1	4	10	21	36
t^3			1	4	11	26;

and taking the sums for the first and second lines only, these are

1, 4, 9, 17, 29, 45 . . .,

which, taken with a negative sign, are the numbers of the line *GF, column 5.

And so as to the Subsidiary of Tables VII. and VIII., each * line of the Table is calculated from a column of Table VII., rejecting the numbers which belong to t^4; thus Table VII., column 4, the numbers are

t^1	1	3	8	15	27	43 ...
t^2		1	4	13	33	74
t^3			1	4	14	38
t^4				1	4	14;

and taking the sums for the first, second, and third lines only, these are

1, 4, 13, 32, 74, 155 . . .,

which, taken with a negative sign, are the numbers of the line *GF, column 5.

Referring to the foregoing "Edification Diagram," the effect is that we thus introduce the conditions that in a boron-tree the number of component trees $a, b, ..$ is at most $(3-1=)2$ and that in a carbon-tree the number of component trees $a, b, ..$ is at most $(4-1=)3$.

TABLE III.—Oxygen Root-trees.

Index x, or number of knots.	Index t, or number of main branches.	Altitude or number of column.												
		0	1	2	3	4	5	6	7	8	9	10	11	12
1	0	1												
2	1		1											
3	1			1										
	2		1											
4	1				1									
	2			1										
5	1					1								
	2			1	1									
6	1						1							
	2				1	1								
7	1							1						
	2				1	1	1							
8	1								1					
	2					1	1	1						
9	1									1				
	2					1	1	1	1					
10	1										1			
	2						1	1	1	1				
11	1											1		
	2						1	1	1	1	1			
12	1												1	
	2							1	1	1	1	1		
13	1													1
	2							1	1	1	1	1	1	

TABLE IV.—Oxygen Centre- and Bicentre-Trees.

Index x, or number of knots.	Index t, or number of main branches.	Centre-Trees. Altitude or number of column							Centre.	Total.	Bicentre.	Bicentre-Trees. Altitude.					
		0	1	2	3	4	5	6				0	1	2	3	4	5
1	0	1							1	1	0						
2									0	1	1	1					
3	2		1						1	1	0						
4									0	1	1		1				
5	2			1					1	1	0						
6									0	1	1			1			
7	2				1				1	1	0						
8									0	1	1				1		
9	2					1			1	1	0						
10									0	1	1					1	
11	2						1		1	1	0						
12									0	1	1						1
13	2							1	1	1	0						

Subsidiary Table for GF's of Tables III. and IV.

Index *t*.	Index of *x*. 0	1	2	3	4	5	6	7	8	9	10	11	12	13	
0															GF, column 0.
*		−1													GF, column 1.
0	1														First factor
1		1													
2			1												
0		1													Second factor.
*			−1												GF, column 2
0	1														First factor.
1			1												
2					1										
0		1													Second factor.
1			1												
*				−1											GF, column 3.
0	1														First factor.
1				1	·	·	·								
2							1								
0		1													Second factor.
1			1	1											
*					−1										GF, column 4.

0	1														First factor.
1					1										
2						.	.	.	1						
0		1													Second factor.
1			1	1	1										
*						−1									GF, column 5.
0	1														First factor.
1						1									
2											1				
0		1													Second factor.
1			1	1	1	1									

and so on indefinitely; viz. observing that the first factors, as shown by the Table, are $(1-tx)^{-1}[t^{1\cdot 2}]$, $(1-tx^2)^{-1}[t^{1\cdot 2}]$ &c., the Table in fact shows that as regards Table III. the GF's are for

column 0 x
,, 1 $tx+t^2x^2 \quad . \, x$
,, 2 $tx^2+t^2x^4 \quad . \, x+tx^2$
,, 3 $tx^3+t^2x^6 \quad . \, x+t(x^2+x^3)$
,, 4 $tx^4+t^2x^8 \quad . \, x+t(x^2+x^3+x^4)$
,, 5 $tx^5+t^2x^{10} \quad . \, x+t(x^2+x^3+x^4+x^5)$;
:

viz. developing as far as t^2, that the successive GF's are

column 0 x
,, 1 $tx^2+t^2x^3$
,, 2 $tx^3+t^2(x^4+x^5)$
,, 3 $tx^4+t^2(x^5+x^6+x^7)$
,, 4 $tx^5+t^2(x^6+x^7+x^8+x^9)$
,, 5 $tx^6+t^2(x^7+x^8+x^9+x^{10}+x^{11})$
&c., agreeing with Table III.

And so also it shows that as regards Table IV. (centre part) the GF's of the successive columns are for

column 0 x
,, 1 $t^2x^2 \quad . \, x$
,, 2 $t^2x^4 \quad . \, x$
,, 3 $t^2x^6 \quad . \, x$
,, 4 $t^2x^8 \quad . \, x$
,, 5 $t^2x^{10} \quad : \, x$
:

viz. that the successive GF's are x, t^2x^3, t^2x^5, t^2x^7, t^2x^9, t^2x^{11}.., agreeing in fact with Table IV.

TABLE V.—Boron Root-trees.

Index *x*, or number of knots.	Index *t*, or number of main branches.	Altitude or number of column.													
		0	1	2	3	4	5	6	7	8	9	10	11	12	
1	0	1	1												
	Total	1	**1**												
2	1		1	1											
	Total		1	**1**											
3	1			1	1										
	2		1		1										
	Total		1	1	**2**										
4	1			1	1	2									
	2			1		1									
	3		1			1									
	Total		1	2	1	**4**									
5	1				2	1	3								
	2			2	1		3								
	3			1			1								
	Total			3	3	1	**7**								
6	1				2	3	1	6							
	2			1	3	1		5							
	3			2	1			3							
	Total			3	6	4	1	**14**							

7	1				1	5	4	1	11						
	2			1	6	4	1		12						
	3			2	3	1			6						
	Total			3	10	10	5	1	**29**						
8	1				1	7	9	5	1	23					
	2				7	10	5	1		23					
	3			2	7	4	1			14					
	Total			2	15	21	15	6	1	**60**					
9	1					8	17	14	6	1	46				
	2				9	21	15	6	1		52				
	3			1	11	11	5	1			29				
	Total			1	20	40	37	21	7	1	**127**				
10	1					9	29	32	20	7	1	98			
	2				7	36	37	21	7	1		109			
	3			1	18	26	16	6	1			68			
	Total			1	25	71	82	59	28	8	1	**275**			
11	1					7	45	66	53	27	8	1	207		
	2				7	59	82	59	28	8	1		244		
	3				21	53	43	22	7	1			147		
	Total				28	119	170	147	88	36	9	1	**598**		
12	1					7	66	127	125	81	35	9	1	451	
	2				4	82	165	147	88	36	9	1		532	
	3				26	102	105	66	29	8	1			337	
	Total				30	191	336	340	242	125	45	10	1	**1320**	
13	1					4	89	231	274	213	117	44	10	1	983
	2				3	114	316	340	242	125	45	10	1		1196
	3				26	175	236	177	96	37	9	1			757
	Total				29	293	641	748	612	375	171	55	11	1	**2936**

TABLE VI.—Boron Centre- and Bicentre-Trees.

or number of knots.	Index *t*, or number of main branches.	Centre-Trees. Altitude or number of columns.								Centre.	Grand Total.	Bicentre.	Bicentre-Trees. Altitude.					
		0	1	2	3	4	5	6					0	1	2	3	4	5
1	0	1	1															
	Total	1	**1**							1	1	0						
2																		
										0	1	1	1					
3	2		1	1														
	Total		1	**1**						1	1	0						
4	2		1	1														
	Total		1	**1**						1	2	1		1				
5	2			1	1													
	Total			1	**1**					1	2	1		1				
6	2 3			1 1	1 1													
	Total			2	**2**					2	4	2		1	1			

7	2 3			1 2	1	2 2												
	Total			3	1	**4**				4	6	2			2			
8	2 3			2	2 1	2 2												
	Total			2	3	**5**				5	11	6			5	1		
9	2 3			1	5 3	1	6 4											
	Total			1	8	1	**10**			10	18	8			5	3		
10	2 3			1	5 9	3 1	8 11											
	Total			1	14	4	**19**			19	37	18			6	11	1	
11	2 3				6 14	11 4	1	18 18										
	Total				20	15	1	**36**		36	66	30			4	22	4	
12	2 3				4 21	22 16	4 1	30 38										
	Total				25	38	5	**68**		68	135	67			3	44	19	1
13	2 3				3 24	44 42	19 5	1	67 71									
	Total				27	86	24	1	**138**	138	265	127			1	68	53	5

Subsidiary Table for GF's of Tables V. and VI.

Index *t*.	Index of *x*. 0	1	2	3	4	5	6	7	8	9	10	11	12	13	
0		1													GF, column 0.
*		−1													GF, column 1.
0	1														First factor.
1		1													
2			1												
3				1											
0		1													Second factor.
*			−1	−1											GF, column 2.
0	1														First factor.
1			1	1											
2					1	1	1								
3							1	1	1	1					
0		1													Second factor.
1			1												
2				1											
*				−1	−2	−2	−1	−1							GF, column 3.
0	1														First factor.
1				1	2	2	1	1							
2							1	2	5	5	6	4	3		
3										1	2	5	9		

0		1													Second factor.
1			1	1	1										
2				1	1	2	1	1							
*					−1	−3	−5	−7	−8	−9	−7	−7	−4	−3	GF, column 4.
0	1														First factor.
1					1	3	5	7	8	9	7	7	4		
2									1	3	11	22	44		
3													1		
0		1													Second factor.
1			1	1	2	2	2	1	1						
2				1	1	3	4	7	7	7	7	7	4	3	
*						−1	−4	−9	−17	−29	−45	−66	−89	−118	GF, column 5.
0	1														First factor.
1						1	4	9	17	29	45	66	89		
2											1	4	19		
0		1													Second factor.
1			1	1	2	3	5	6	8	8	9	7	7	4	
2				1	1	3	5	11	17	30	43	66	86	117	
*							−1	−5	−14	−32	−66	−127	−231	−405	GF, column 6,
0	1														First factor.
1							1	5	14	32	66	127	231		
2													1		
0		1													Second factor.
1			1	1	2	3	6	10	17	25	38	52	73	93	
2				1	1	3	5	12	22	45	80	148	251	433	

Subsidiary Table for GF's of Tables V. and VI. (*continued*).

Index t.	Index of x.														
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	
*								−1	−6	−20	−53	−125	−274	−571	GF, column 7.
0	1														First factor.
1								1	6	20	53	125	274		
0		1													Second factor.
1			1	1	2	3	6	11	22	39	70	118	200	324	
2				1	1	3	5	12	23	51	101	207	398	773	
*									−1	−7	−27	−81	−213	−516	GF, column 8.
0	1														First factor.
1									1	7	27	81	213		
0		1													Second factor.
1			1	1	2	3	6	11	23	45	90	171	325	598	
2				1	1	3	5	12	23	52	108	235	486	1015	
*										−1	−8	−35	−117	−338	GF, column 9.
0	1														First factor.
1										1	8	35	117		
0		1													Second factor.
1			1	1	2	3	6	11	23	46	97	198	406	811	
2				1	1	3	5	12	23	52	109	243	522	1140	

*											−1	−9	−44	−162	GF, column 10.
0 1	1										1	9	44		First factor.
0 1 2		1	1	1 1	2 1	3 3	6 5	11 12	23 23	46 52	98 109	206 244	441 531	928 1185	Second factor.
*												−1	−10	−54	GF, column 11.
0 1	1											1	10		First factor.
0 1 2		1	1	1 1	2 1	3 3	6 5	11 12	23 23	46 52	98 109	207 244	450 532	972 1195	Second factor.
*													−1	−11	GF, column 12.
0 1	1												1		First factor.
0 1 2		1	1	1 1	2 1	3 3	6 5	11 12	23 23	46 52	98 109	207 244	451 532	982 1196	Second factor.
*														−12	GF, column 13.
0	1														First factor.
0 1 2		1	1	1 1	2 1	3 3	6 5	11 12	23 23	46 52	98 109	207 244	451 532	983 1196	Second factor.

TABLE VII.—Carbon Root-trees.

Index *x*, or number of knots.	Index *t*, or number of main branches.	Altitude or number of column.													
		0	1	2	3	4	5	6	7	8	9	10	11	12	
1	0	1	1												
	Total	1	**1**												
2	1		1	1											
	Total		1	**1**											
3	1			1	1										
	2		1		1										
	Total		1	1	**2**										
4	1			1	1	2									
	2			1		1									
	3		1			1									
	Total		1	2	1	**4**									
5	1			1	2	1	4								
	2			2	1		3								
	3			1			1								
	4		1				1								
	Total		1	4	3	1	**9**								
6	1				4	3	1	8							
	2			2	3	1		6							
	3			2	1			3							
	4			1				1							
	Total			5	8	4	1	**18**							
7	1				4	8	4	1	17						
	2			2	8	4	1		15						
	3			3	3	1			7						
	4			2	1				3						
	Total			7	16	13	5	1	**42**						

8	1				5	15	13	5	1	39					
	2			1	13	13	5	1		33					
	3			3	9	4	1			17					
	4			3	3	1				7					
	Total			7	30	33	19	6	1	**96**					
9	1				4	27	32	19	6	1	89				
	2			1	22	33	19	6	1		82				
	3			3	17	14	5	1			40				
	4			4	9	4	1				18				
	Total			8	52	78	57	26	7	1	**229**				
10	1				4	43	74	56	26	7	1	211			
	2				29	74	57	26	7	1		194			
	3			3	34	38	20	6	1			102			
	4			4	18	14	5	1				42			
	Total			7	85	169	156	89	34	8	1	**549**			
11	1				3	67	155	151	88	34	8	1	507		
	2				40	154	156	89	34	8	1		482		
	3			2	54	95	63	27	7	1			249		
	4			5	38	39	20	5	1				108		
	Total			7	135	355	394	272	130	43	9	1	**1346**		
12	1				2	97	316	374	267	129	43	9	1	1238	
	2				46	297	389	273	130	43	9	1		1188	
	3			1	88	218	184	96	35	8	1			631	
	4			4	66	100	64	27	7	1				269	
	Total			5	202	712	953	770	439	181	53	10	1	**3326**	
13	1				1	136	612	889	743	432	180	52	10	1	3056
	2				55	550	929	770	439	181	53	10	1		2988
	3			1	127	474	491	309	138	44	9	1			1594
	4			4	117	239	190	97	35	8	1				691
	Total			5	300	1399	2222	2065	1355	665	243	63	11	1	**8329**

TABLE VIII.—Carbon Centre- and Bicentre-Trees.

Index *x*, or number of knots.	Index *t*, or number of main branches.	Centre-Trees. Altitude or number of column.								Centre.	Grand total.	Bicentre.	Bicentre-Trees. Altitude.					
		0	1	2	3	4	5	6					0	1	2	3	4	5
1	0	1	1															
	Total	1	**1**							1	1	0						
2																		
										0	1	1	1					
3	2		1	1														
	Total		1	**1**						1	1	0						
4	2		1	1														
	Total		1	**1**						1	2	1		1				
5	2		1	1	2													
	Total		1	1	**2**					2	3	1		1				
6	2 3			1 1	1 1													
	Total			2	**2**					2	5	3		2	1			
7	2 3 4			2 2 1	1	3 2 1												
	Total			5	1	**6**				6	9	3		1	2			

8	2			1	2	3												
	3			3	1	4												
	4			2		2												
	Total			6	3	**9**				9	18	9		1	7	1		
9	2			1	7	1	9											
	3			3	3		6											
	4			4	1		5											
	Total			8	11	1	**20**			20	35	15			12	3		
10	2				12	3	15											
	3			3	11	1	15											
	4			4	3		7											
	Total			7	26	4	**37**			37	75	38			23	14	1	
11	2				23	14	1	38										
	3			2	24	4		30										
	4			5	12	1		18										
	Total			7	59	19	1	**86**		86	159	73			30	39	4	
12	2				30	39	4	73										
	3			1	54	19	1	75										
	4			4	27	4		35										
	Total			5	111	62	5	**183**		183	357	174			42	108	23	1
13	2				42	108	23	1	174									
	3			1	88	63	5		157									
	4			4	63	20	1		88									
	Total			5	193	191	29	1	**419**	419	799	380			47	244	84	5

Subsidiary Table for GF's of Tables VII. and VIII.

Index *t*.	Index of *x*.														
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	
0		1													GF, column 0.
*		−1													GF, column 1.
0	1														First factor.
1		1													
2			1												
3				1											
4					1										
0		1													Second factor.
*			−1	−1	−1										GF, column 2.
0	(1)														First factor.
1			1	1	1										
2					1	1	2	1	1						
3							1	1	2	2	2	1	1		
4									1	1	2	2	3		
0		1													Second factor.
1			1												
2				1											
3					1										
*				−1	−2	−4	−4	−5	−4	−4	−3	−2	−1	−1	GF, column 3.
0	(1)														First factor.
1				1	2	4	4	5	4	4	3	2	1		
2							1	2	7	12	23	30	42		
3										1	2	7	16		
4													1		

0		1													Second factor.
1			1	1	1	1									
2				1	1	2	2	2	1	1					
3					1	1	2	3	3	3	3	2	1	1	
*					−1	−3	−8	−15	−27	−43	−67	−97	−136	−183	GF, column 4.
0	(1)														First factor.
1					1	3	8	15	27	43	67	97	136		
2									1	3	14	39	108		
3													1		
0		1													Second factor.
1			1	1	2	3	4	4	5	4	4	3	2	1	
2				1	1	3	5	10	14	23	29	40	46	55	
3					1	1	3	6	12	20	37	56	89	128	
*						−1	−4	−13	−32	−74	−155	−316	−612	−1160	GF, column 5.
0	(1)														First factor.
1						1	4	13	32	74	155	316	612		
2											1	4	23		
0		1													Second factor.
1			1	1	2	4	7	12	20	31	47	70	99	137	
2				1	1	3	6	14	27	56	103	194	343	605	
3					1	1	3	7	16	34	75	151	307	602	
*							−1	−5	−19	−56	−151	−374	−889	−2032	GF, column 6.
0	1														First factor.
1							1	5	19	56	151	374	889		
2													1		
0		1													Second factor.
1			1	1	2	4	8	16	33	63	121	225	415	749	
2				1	1	3	6	15	32	75	160	350	732	1534	
3					1	1	3	7	17	39	95	214	491	1093	

Subsidiary Table for GF's of Tables VII. and VIII. (*continued*).

Index *t*.	Index of *x*.														
	0	1	2	3	4	5	6	7	8	9	10	11	12	13	
*								−1	−6	−26	−88	−267	−743	−1968	GF, column 7.
0	(1)														First factor.
1								1	6	26	88	267	743		
0		1													Second factor.
1			1	1	2	4	8	17	38	82	177	376	789	1638	
2				1	1	3	6	15	33	81	186	439	1005	2304	
3					1	1	3	7	17	40	101	241	587	1402	
*									−1	−7	−34	−129	−432	−1320	GF, column 8.
0	(1)														First factor.
1									1	7	34	129	432		
0		1													Second factor.
1			1	1	2	4	8	17	39	88	203	464	1056	2381	
2				1	1	3	6	15	33	82	193	473	1135	2743	
3					1	1	3	7	17	40	102	248	622	1540	
*										−1	−8	−43	−180	−657	GF, column 9.
0	(1)														First factor.
1										1	8	43	180		
0		1													Second factor.
1			1	1	2	4	8	17	39	89	210	498	1185	2813	
2				1	1	3	6	15	33	82	194	481	1178	2924	
3					1	1	3	7	17	40	102	249	630	1584	

*											−1	−9	−53	−242	GF, column 10.
0	(1)														First factor.
1											1	9	53		
0		1													Second factor.
1			1	1	2	4	8	17	39	89	211	506	1228	2993	
2				1	1	3	6	15	33	82	194	482	1187	2977	
3					1	1	3	7	17	40	102	249	631	1593	
*												−1	−10	−63	GF, column 11.
0	(1)														First factor.
1												1	10	63	
0		1													Second factor.
1			1	1	2	4	8	17	39	89	211	507	1237	3048	
2				1	1	3	6	15	33	82	194	482	1188	2987	
3					1	1	3	7	17	40	102	249	631	1594	
*													−1	−11	GF, column 12.
0	(1)														First factor.
1													1	11	
0		1													Second factor.
1			1	1	2	4	8	17	39	89	211	507	1238	3055	
2				1	1	3	6	15	33	82	194	482	1188	2988	
3					1	1	3	7	17	40	102	249	631	1594	
*														−1	GF, column 13.
0	(1)														First factor.
1														1	
0		1													Second factor.
1			1	1	2	4	8	17	39	89	211	507	1238	3056	
2				1	1	3	6	15	33	82	194	482	1188	2988	
3					1	1	3	7	17	40	102	249	634	1594	

I annex the following two Tables of (centre- and bicentre-) trees as far as I have completed them.

TABLE A.

Knots.	Valency not greater than									Gen.
	0	1	2 Oxygen.	3 Boron.	4 Carbon.	5	6	7	8	
1	1	1	1	1	1	1	1	1	1	1
2		1	1	1	1	1	1	1	1	1
3			1	1	1	1	1	1	1	1
4			1	2	2	2	2	2	2	2
5			1	2	3	3	3	3	3	3
6			1	4	5	6	6	6	6	6
7			1	6	9	10	11	11	11	11
8			1	11	18	21	22	23	23	23
9			1	18	35	42	45	46	47	47
10			1	37	75					106
11			1	66	159					235
12			1	135	357					551
13			1	265	799					1301

TABLE B.

Knots.	Actual Valency.								
	0	1	2	3	4	5	6	7	8
1	1								
2		1							
3			1						
4			1	1					
5			1	1	1				
6			1	3	1	1			
7			1	5	3	1	1		
8			1	10	7	3	1	1	
9			1	17	17	7	3	1	1
10			1	36	38				
11			1	65	93				
12			1	134	222				
13			1	264	534				

viz. in A the columns 2, 3, 4, and the last column are the totals given by the Tables IV., VI., VIII., and II., and the remaining numbers of columns 5, 6, 7, 8 have been found by trial; and in B the several columns are the differences of the columns of A. The signification is obvious; for instance, if the number of knots is =9, then Table A, if valency, or maximum number of branches from a knot,

is = 2, 3, 4, 5, 6, 7, 8 or any greater number,
No. of trees = 1, 18, 35, 42, 45, 46, 47:

viz. with 9 knots the tree can have at most 8 branches from a knot, so that the number of trees having at most 8 branches from a knot is =47, the whole number of trees with 9 knots; and so the number of knots being as before =9, Table B shows that the number of 47 is made up of the numbers

1, 17, 17, 7, 3, 1, 1;

viz. 1 is the No. of trees, at most 2 branches from a knot,
17 " " 3 " " at least one 3-branch knot.
17 " " 4 " " " 4 "
7 " " 5 " " " 5 "
3 " " 6 " " " 6 "
1 " " 7 " " " 7 "
1 " " 8 " " " 8 "

I annex also a Plate showing the figures of the 1+1+2+3+6+11+23+47 trees of 1, 2, 3 . . . 9 knots, classified according to their altitudes and number of main branches; and as to the bicentre-trees, according to the number of main branches from *each* point of the bicentre. The affixed numbers show in each case the greatest number of branches from a knot; so that when this is (2), the knots may be oxygen, boron, carbon, &c. atoms; when (3), boron, carbon, &c. atoms; when (4), carbon, &c. atoms; and so on.

Report of the Committee, consisting of Professor CAYLEY, *F.R.S.*, Professor STOKES, *F.R.S.*, Professor Sir W. THOMSON, *F.R.S.*, Professor H. J. S. SMITH, *F.R.S.*, *and* J. W. L. GLAISHER, *F.R.S.*, *on Mathematical Tables.* (Professor CAYLEY, Reporter.)

THE present Report (say Report 1875) is in continuation of that by Mr. Glaisher, published in the volume for 1873, and here cited as Report 1873.

Report 1873 extends to all those tables which are at p. 3 included under the headings:—

A, auxiliary for non-logarithmic calculation, 1, 2, 3;
B, logarithmic and circular, 4, 5, 6;
C, exponential, 7, 8 (but only partially to C 8), other than those tables of C referred to as "h . l tan $(45°+\frac{1}{2}\phi)$;" and also partially (see art. 24, pp. 81–83) to the tables included under the heading "E. 11, transcendental constants ϵ, π, γ, &c., and their powers and functions."

A future Report will comprise the tables, or further tables, included under the headings:—

C. 8. Hyperbolic antilogarithms (e^x) and h . l tan $(45°+\frac{1}{2}\phi)$, and hyperbolic sines, cosines, &c.

D. Algebraic constants.
- 9. Accurate integer or fractional values. Bernoulli's Nos., $\Delta^n 0^m$, &c. Binomial coefficients.
- 10. Decimal values auxiliary to the calculation of series.

E. 11. Transcendental constants ϵ, π, γ, &c., and their powers and functions.

The present Report (1875) comprises the tables included under the headings:—

F. Arithmological.
- 12. Divisors and prime numbers. Prime roots. The Canon arithmeticus, &c.
- 13. The Pellian equation.
- 14. Partitions.
- 15. Quadratic forms a^2+b^2 &c., and partition of numbers into squares, cubes, and biquadrates.
- 16. Binary, ternary, &c. quadratic and higher forms.
- 17. Complex theories,

which divisions are herein referred to, for instance, as [F. 12. Divisors &c.].

Report 1873 consists of six sections (§) divided into articles, which are separately numbered (see contents, p. 174); the present Report 1875 forms a single section (§ 7), divided in like manner into articles, which are separately numbered; but besides this the paragraphs are numbered, and that continuously, through the present Report 1875, so that any paragraph may be cited as Report 1875, No. — (as the case may be).

Art. 1. [F. 12, *Divisors &c.*] *Divisors and Prime Numbers.*

1. As to divisors and prime numbers see Report 1873, art. 8 (Tables of Divisors (factor tables) and Tables of Primes), pp. 34–40. The tables there referred to, such as Chernac, Burckhardt, Dase, Dase and Rosenberg, are chiefly tables running up to very high numbers (the last of them the ninth million), wherein to save space multiples of 2, 3, 5 are frequently omitted, and in some of them only the least divisor is given. It would be for many purposes convenient to have a small table, going up say to 10,000, showing in every case all the prime factors of the number. Such a table might be arranged, 500 numbers in a page, in some such form as the following:—

Factor Table | 1 to 500 |

	0	1	2	3	4	5	6	7	8	9
39	2.3.5.13	17.23	$2^3.7^2$	3.131	2.197	5.79	$2^2.3^2.11$	397*	2.199	3.7.19

where the top line shows the units, and the left-hand column the remaining figures, viz. the specimen exhibits the composition of the several numbers from 390 to 399: a prime number, *e.g.* 397, would be sufficiently indicated by the absence of any decomposition, or it may be further indicated by an asterisk.

It may be noticed that in the theory of numbers the decomposition is specially required when the next following number is a prime, viz. that of $p-1$, p being a prime: and that this is given incidentally, for prime numbers p up to 1000, in Jacobi's 'Canon Arithmeticus,' *post*, No. 20, and up to 15,000 in Reuschle's Tables, V. (a, b, c) *post*, No. 22.

2. It may be proper to remark here that any table of a binary form is really a factor-table in the complex theory connected with such binary form.

Thus in a table of the form a^2+b^2, a number of this form has a factor $a+bi$ ($i=\sqrt{-1}$ as usual); and the table in fact shows the complex factor $a+bi$ of the number in question: a well arranged table would give all the prime complex factors $a+bi$ of the number. But as to this more hereafter; at present we are concerned with the real theory only, not with any complex theory.

3. Connected with a factor-table we have (1) Table of the number of less relative primes; viz. such a table would show for every number the number of inferior integers having no common factor with the number itself. The formula is a well-known one: for a number $N=a^{\alpha}b^{\beta}c^{\gamma}\ldots$, ($a, b,\ldots$ the distinct prime factors of N), the number of less relative primes is

$$\varpi(N), =a^{\alpha-1}b^{\beta-1}\ldots(a-1)(b-1),\ldots,$$

or, what is the same thing, $=N\left(1-\frac{1}{a}\right)\left(1-\frac{1}{b}\right)\ldots$ A small table (N=1 to 100), occupying half a page, is given,

Euler, Op. Arith. Col. t. ii. p. 128; viz. this is $\pi 1=0$, $\pi 2=1,\ldots\pi 100=40$.

4. But it would be interesting to have such a table of the same extent with the proposed factor-table. The table might be of like form; for instance,

No. of less relative Primes Table $\boxed{1 \text{ to } 500}$.

	0	1	2	3	4	5	6	7	8	9
29	112	192	144	292	84	232	144	198	148	264

and it would be of still greater interest to have an inverse table showing the values of N which belong to a given value of $\varpi(N)$; for instance,

$\varpi=$	N=
40	41, 55, 75, 82, 88, 100, 110
42	43, 49, 86, 98
44	69, 92
46	47, 94
48	65, 104, 105, 112
⋮	

where, observe, that ϖ is of necessity even.

5. Again, connected with a factor-table, we have (2) Table of the **Sum** of the divisors of a Number. The formula is also a well-known one; for a number $N=a^{\alpha}b^{\beta}\ldots$, ($a$, b the distinct prime factors of N), the required sum $\int N$ is $=(1+a\ldots+a^{\alpha})(1+b\ldots+b^{\beta}),\ldots$, or, what is the same thing, $=\frac{a^{\alpha+1}-1}{a-1}\cdot\frac{b^{\beta+1}-1}{b-1}\ldots$, where, observe, that the number itself is reckoned as a divisor.

6. Such a table was required by Euler in his researches on Amicable Numbers (see *post*, No. 10), and he accordingly gives one of a considerable extent,

Euler, Op. Arith. Coll. t. i. pp. 104–109.

It is to be remarked that inasmuch as $\int N$ is obviously $=\int a^{\alpha}\int b^{\beta}\ldots$, the function need only be tabulated for the different integer powers a^{α} of each prime number a. The range of Euler's table is as follows:—

$a=$	$\alpha=$
2	1 to 36
3	1 „ 15
5	1 „ 9
7	1 „ 10
11	1 „ 9
13	1 „ 7
17	1 „ 5
19	1 „ 5
23	1 „ 4
29 to 997	1 „ 3

viz. for the several prime numbers from 29 to 997 the table gives $\int a$, $\int a^2$, and $\int a^3$. And it is to be noticed that the values of the sum are exhibited, decomposed into their prime factors: thus a specimen of the table is

Num.	Summa Divisorum.
139	$2^2.5.7$
139^2	$3.13.499$
139^3	$2^3.5.7.9661$

7. The form of the above table is adapted to its particular purpose (the theory of amicable numbers); but Euler gives also,

Euler, Op. Arith. Coll. t. i. p. 147 (in the paper "Observatio de Summis Divisorum," pp. 146–154, 1752), a short table of about half a page, N=1 to 100, of the form $\int 1=1$, $\int 2=3, \ldots \int 100=217$. The paper contains on the subject of $\int$N interesting analytical researches which connect themselves with the theory of the Partition of Numbers.

8. It would be interesting to carry the last-mentioned table to the same extent as the proposed factor-table; and to add to it an inverse table, as suggested in regard to the number of less relative primes table.

9. *Perfect Numbers.*—A perfect number is a number which is equal to the sum of its divisors (the number itself not being reckoned as a divisor), *e. g.* $6=1+2+3$: $28=1+2+4+7+14$. Such numbers are indicated by a table of the sums of divisors $\int 6=12$, $\int 28=56$, these two being, as appears by the table, art. 7, the only perfect numbers less than 100.

10. *Amicable Numbers.*—These are pairs of numbers such that each is equal to the sum of the divisors of the other (not reckoning the other number as a divisor); or, what is the same thing, such that each has the same sum of divisors (the number being here reckoned as a divisor); say $\int' \mathrm{A}=\mathrm{B}$, $\int' \mathrm{B}=\mathrm{A}$; or, what is the same thing, $\int \mathrm{A}=\int \mathrm{B}(=\mathrm{A}+\mathrm{B})$. Thus 220, 284,

$$\int' 220=(1+2+4)(1+5)(1+11)-220, \ =284,$$

$$\int' 284=(1+2+4)(1+71)-284, \qquad =220;$$

or, what is the same thing,

$$\int 220=(1+2+4)(1+5)(1+11)=504=(1+2+4)(1+71)=\int 284.$$

11. A catalogue of 61 pairs of numbers is given

Euler, Op. Arith. Coll. t. i. pp. 144–145 (occupies about one page). The paper, "De Numeris Amicabilibus," pp. 102–145, contains an elaborate investigation of the theory, by means whereof all but two of the pairs of numbers are obtained. The first pair is the above-mentioned one, $2^2.5.11$ and $2^2.71$(=220 and 284), and the fifty-ninth the high numbers

$$3^5.7^2.13.19.53.6959 \text{ and } 3^5.7^2.13.19.179.2087.$$

The last two pairs are referred to as "formæ diversæ a precedentibus;" viz. these are

$$\begin{cases} 2^3.19.41 \\ 2^5.199 \end{cases} \text{and} \begin{cases} 2^3.41.467 \\ 2^5.19.233. \end{cases}$$

12. A Table of the Frequency of Primes is given

Gauss, Tafel der Frequenz de Primzahlen, Werke, t. xi. pp. 436–443; viz. this extends to 3,000,000.

The first part, extending to 1,000,000, =1000 thousand, shows how many primes there are in each thousand: a specimen is

1, 168
2, 135
3, 127
4, 120
5, 119
&c.;

viz. in the first thousand there are 168 primes, in the second thousand 135 primes, and so on.

For the second and third millions the frequency is given for each ten thousand: a specimen is

1,000,000 to 1,100,000.

	0	1	2	3	4	5	6	7	8	9	
1	1										1
2		1				1		1	1		4
3		4	2	2	3	1	2	3	3	1	12
4	2	8	5	4	3	6	9	4	5	8	54
5	11	10	8	18	12	10	10	12	15	8	114
6	14	14	18	21	16	22	19	15	17	15	171
7	26	17	23	23	24	24	17	22	20	21	217
8	19	16	21	7	14	15	20	17	15	17	164
9	11	13	9	13	14	14	12	13	11	16	126
10	8	6	8	5	9	5	5	9	7	9	71
11	6	6	4	6	3	1	3	1	4	5	39
12	1	1	2	1	1	1	2	2	1		12
13	1	1			1		1	1	1		6
14											
15											
16											
	752	719	732	700	731	698	713	722	760	737	7210

$$\int \frac{dx}{\log x} = 7212{\cdot}99.$$

viz. in the interval 1,000,000 to 1,010,000, 100 hundreds, there is 1 hundred containing 1 prime, 2 hundreds each containing 4 primes, 11 hundreds each containing 5 primes, ... 1 hundred containing 13 primes,

$$\begin{array}{rrr} 1\times & 1= & 1 \\ 4\times & 2= & 8 \\ 5\times & 11= & 55 \\ \vdots & & \\ 13\times & 1= & 13 \\ \hline 100 & & 752 \end{array}$$

or the whole 10,000 contains 752 primes; the next 10,000 contains 719 primes, and so on; the whole 100,000 thus containing $752+719+\&c.\ldots=7210$ primes, which number is at the foot compared with the theoretic approximate value $\int\frac{dx}{\log x}$ (limits 1,000,000 to 1,010,000)$=7212{\cdot}99$. The integral in question is represented by the notation Li. x or li. x.

p. 443. We have the like tables 1,000,000 to 2,000,000 and 2,000,000 to 3,000,000, showing for each 100,000 how many hundreds there are containing 0 prime, 1 prime, 2 primes, up to (the largest number) 17 primes.

13. It is noticed that

the 26,379th hundred contains no prime,
the 27,050th hundred contains 17 primes.

It may be observed that if $N=2\,.\,3\,.\,5\,\ldots p$, the product of all the primes up to p, then each of the numbers $N+1$ and $N+q$ (if q be the prime next succeeding p) is or is not a prime; but the intermediate numbers $N+2$, $N+3, \ldots N+q-1$ are certainly composite; viz. we thus have at least $q-2$ consecutive composites. To obtain in this manner 99 consecutive composites, the value of N would be $=2\,.\,3\,.\,5\ldots 97$, viz. this is a number far exceeding 2,637,900; but in fact the hundred numbers 2,637,901 to 2,638,000 are all composite.

Legendre, in his 'Essai sur la Théorie des Nombres' (1st edit., 1798; 2nd edit., 1808; supplement, 1816: references to this edition), gives for the number of primes inferior to a given limit x the approximate formula

$$\frac{x}{\log x-1{\cdot}08366};$$

and p. 394, and supplement, p. 62, he compares for each 10,000 up to 100,000, and for each 100,000 up to 1,000,000, the values as computed by this formula with the actual numbers of primes exhibited by the tables of Wega and Chernac. Thus $x=1{,}000{,}000$, the computed value is 78,543, the actual value 78,493.

He shows, p. 414, that the number of integers less than n, and not divisible by any of the numbers θ, λ, μ, ... is approximately

$$=n\left(1-\frac{1}{\theta}\right)\left(1-\frac{1}{\lambda}\right)\left(1-\frac{1}{\mu}\right)\ldots;$$

and taking θ, λ, μ ... the successive primes 3, 5, 7, ... he gives the values of the function in question, or, say, the function

$$\frac{2}{3}\cdot\frac{4}{5}\cdot\frac{6}{7}\cdot\frac{10}{11}\cdots\frac{\omega-1}{\omega},$$

ω a prime, for the several prime values $\omega=3$ to 1229 in the Table IX. (one page) at the end of the work.

14. A table of frequency is given

Glaisher, J. W. L., British Association Report for 1872, p. 20. This gives for the second and ninth millions, respectively divided into intervals of 50,000, the actual number of primes in each interval, as compared with the theoretic value $\text{li}x'-\text{li}x$; and also deduced therefrom, by the formula $\log \frac{1}{2}(x'+x)$, a table of the average interval between two consecutive primes; this average interval increases very slowly: at the beginning and end of the second million the values are 13·76 and 14·58 (theoretic values 13·84 and 14·50); at the beginning and end of the ninth million 16·02 and 15·95 (theoretic values 15·90 and 16·01).

15. Coming under the head of Divisor Tables, some tables by Reuschle and Gauss may be here referred to. These are:—

Reuschle, Mathematische Abhandlung, zahlentheoretische Tabellen sammt einer dieselben treffenden Correspondenz mit der verewigten C. G. J. Jacobi, 4°, pp. 1–61 * (1856). The tables belonging to the present subject are

A. Tafeln zur Zerlegung von a^n-1 (pp. 18–22).

I. Table of the prime factors of 10^n-1, viz.

(a. pp. 18–19). Complete decomposition of 10^n-1 ($n=1$ to 42) and 10^n+1 ($n=1$ to 21). Some values of n omitted.

A specimen is

$$10^{13}-1=3^2.53.79.265371653,$$

$$10^{13}+1=11.189.1058313049.$$

(b. p. 19). List of the specific prime factors f of 10^n-1 (or the prime factors of the residue after separation of the analytical factors) for those values of n for which the complete decomposition is unknown, and omitting those values for which no factor is known, $n=25$ to 243.

A specimen is

n	f
25	2141.

The meaning seems to be, residue of $10^{25}-1$ is $1+10^5+10^{10}+10^{15}+10^{20}$, and this contains the prime factor 21401; but it is not clear why this is the "specific prime factor."

II. Prime factors of a^n-1 for different values of a and n.

(a. p. 20) gives for 41 values of a (2, 3, &c. at intervals to 100) and for the following values of n the decompositions of the residues or specific factors of a^n-1; viz. these are

$n=1$	$a-1$
„ 2	$a+1$
„ 3	a^2+a+1
„ 6	a^2-a+1
„ 4	a^2+1
„ 5	$a^4+a^3+a^2+a+1$
„10	$a^4-a^3+a^2-a+1$
„ 8	a^4+1
„12	a^4-a^2+1

---

* Titlepage missing in my copy, but I find from Prof. Kummer's notice of the work, 'Crelle,' t. liii. (1857), p. 379, that it appeared as a Programm of the Stuttgart Gymnasium, Michaelmas, 1856, and was separately printed by Liesching and Co., Stuttgart.

A specimen is

a	$a-1$	a^2-1	a^3-1	a^6-1	a^4-1	a^5-1	$a^{10}-1$	a^8-1	$a^{12}-1$
10	3^2	11	$3^3.37$	7.13	101	41.271	9091	73.137	9901

(b. p. 21.) Specific prime factors for the numbers 2, 3, 5, 6, 7, 10 (the powers 4, 8, 9 being omitted as coming under 2 and 3) for the exponents 1 to 42.

A specimen is

n	2^n-1	3^n-1	5^n-1	6^n-1	7^n-1	10^n-1
19	524287	1597.363889	191.x	191.x	419.x	

where the x denotes that the other factor is not known to be prime. And so where no number is given, as in $10^{19}-1$, it is not known whether the number $(=1+10^1+10^2\ldots+10^{18})$ is or is not prime.

Addition, p. 22. For $a=2$, the complete decomposition of the prime factor of 2^n-1 is given for values of n, $=44, 45\ldots$ at intervals to 156.

A specimen is n	f
44	397.2113,

viz. $2^{20}-2^{18}+2^{16}\ldots-2^2+1, =838.861=397.2113.$

$n=31$, Fermat's prime. $n=37$, the first case for which the decomposition is not given completely. $n=41$, the first case for which no factor is known.

16. **Gauss**, Tafel zur Cyclotechnie, Werke, t. ii. pp. 478–495, shows for 2452 numbers of the several forms a^2+1, a^2+4, a^2+9, ... a^2+81, the values of a such that the number in question is a product of prime factors no one of which exceeds 200, and exhibits all the odd prime factors of each such number. The table is in nine parts, zerlegbare a^2+1, zerlegbare a^2+4, &c., with to each part a subsidiary table, as presently mentioned. Thus a specimen is

zerlegbare a^2+9.

1	5
2	13
4	5.5
5	17
7	29
8	73
⋮	⋮
1411168679	5.5.13.17.17.89.113.157.173.197.197.

viz. 1^2+9, odd prime factor is 5,
2^2+9, „ „ 13,
4^2+9, „ factors are 5, 5,

and so on.

And the subsidiary table is

5	1, 4, 79
13	2, 11, 41
17	5, 29. 46, 379, 1042
⋮	⋮

showing that the numbers a for which the largest factor is 5 are 1, 4, 79; those for which it is 13 are 2, 11, 41; and so on.

The object of the table is explained in the 'Bemerkungen,' p. 499, by Schering, the editor of the volume, viz. it is to facilitate the calculation of the circular arcs the cotangents of which are rational numbers. To take a simple example, it appears to be by means of it that Gauss obtained, among other formulæ, the following:

$$\frac{\pi}{4} = 12 \operatorname{arctan} \frac{1}{18} + 8 \operatorname{arctan} \frac{1}{57} - 5 \operatorname{arctan} \frac{1}{239},$$

and

$$= 12 \operatorname{arctan} \frac{1}{38} + 20 \operatorname{arctan} \frac{1}{57} + 7 \operatorname{arctan} \frac{1}{239} + 24 \operatorname{arctan} \frac{1}{268}.$$

Art. 2. [F. 12. *Divisors &c.*] *continued. Prime Roots. The Canon Arithmeticus, Quadratic residues.*

17. *Prime Roots.*—Let p be a prime number; then there exist $\varpi(p-1)$ inferior integers g, such that all the numbers $1, 2, \dots p-1$ are, to the modulus p, $\equiv 1, g, g^2, \dots g^{p-2}$ (g^{p-1} is of course $\equiv 1$); and this being so, g is said to be a prime root of p; and moreover the several numbers g^α, where α is any number whatever less than and prime to $p-1$, constitute the series of the $\varpi(p-1)$ prime roots of p. It may be added that if β be an integer number less than $p-1$, and having with it a greatest common measure $=k$, so that $(g^\beta)^{\frac{p-1}{k}} \equiv g^{\frac{\beta}{k}(p-1)}, \equiv 1$, $\left(\text{since } \frac{\beta}{k} \text{ is an integer, and } g^{p-1} \equiv 1\right)$ then g^β has the indicatrix $\frac{p-1}{k}$: the prime roots are those numbers which have the indicatrix $p-1$.

The like theory exists as to any number N of the form p^m or $2p^m$. There are here $\varpi(\mathrm{N})$, $=\mathrm{N}\left(1-\frac{1}{p}\right)$ or $\frac{1}{2}\mathrm{N}\left(1-\frac{1}{p}\right)$ (in the two cases respectively) numbers less than N and prime to it; and we have then $\varpi\big(\varpi(\mathrm{N})\big)$ numbers g such that to the modulus N all these numbers are $\equiv 1, g, g^2 \dots g^{\varpi(\mathrm{N})-1}$ ($g^{\varpi(\mathrm{N})}$ is of course $\equiv 1$); and this being so, g may be regarded as a prime root of N ($=p^m$ or $2p^m$ as the case may be); and moreover the several numbers g^α, where α is any number whatever less than and prime to $\varpi(\mathrm{N})$, constitute the series of the $\varpi\big(\varpi(\mathrm{N})\big)$ prime roots of N. Thus $\mathrm{N}=3^2=9$, $\varpi(\mathrm{N})=6$; we have

$$1,\ 2^1,\ 2^2,\ 2^3,\ 2^4,\ 2^5$$
$$\equiv 1,\ 2,\ 4,\ 8,\ 7,\ 5 \mod. 9;$$

or prime roots are 2^1 and 2^5, $=2$ and 5.

So also $\mathrm{N}=2.3^2=18$, $\varpi(\mathrm{N})=6$; we have

$$1,\ 5,\ 5^2,\ 5^3,\ 5^4,\ 5^5$$
$$\equiv 1,\ 5,\ 7,\ 17,\ 13,\ 11 \mod. 18;$$

and 5^1 and 5^5, $=5$ and 11 are the prime roots of 18.

18. A small table of prime roots, $p=3$ to 37, is given

Euler, Op. Arith. Coll. t. i. pp. 525–526. The Memoir is entitled "Demonstrationes circa residua e divisione potestatum per numeros primos resultantia," pp. 516–537 (1772).

19. A table, p and p^m, 3 to 97, is given

Gauss, 'Disquisitiones Arithmeticæ,' 1801 (Werke, t. i. p. 468). This

gives in each case a prime root, and it shows the exponents in regard thereto of the several prime numbers less than p or p^m. Thus a specimen is

		2 .	3 .	5 .	7 .	11 .	13 .	17 .	19 .	23 .	29, &c.
27	2	1	1	5	16	13	8	15	12	11	
29	10	11	27	18	20	23	2	7	15	24	

viz. for 27 we have 2 a prime root, and $2 \equiv 2^1$, $5 \equiv 2^5$, $7 \equiv 2^{16}$, $11 \equiv 2^{13}$, &c.; and so also for 29 we have 10 a prime root and $2 \equiv 10^{11}$, $3 \equiv 10^{27}$, $5 \equiv 10^{18}$, &c.

20. Small tables are probably to be found in many other places; but the most extensive and convenient table is **Jacobi's** 'Canon Arithmeticus,' the complete title of which is

'Canon Arithmeticus sive tabula quibus exhibentur pro singulis numeris primis vel primorum potestatibus infrâ 1000 numeri ad datos indices et indices ad datos numeros pertinentes.' Edidit C. G. J. Jacobi. Berolini, 1839. 4º.

The contents are as follows:—

	Page
Introductio	i to xl
Tabulæ numerorum ad indices datos pertinentium et indicum numero dato correspondentium pro modulis primis minoribus quam 1000	1–221
Tabulæ residuorum et indicum sibi mutuo respondentium pro modulis minoribus quam 1000 qui sunt numerorum primorum potestates	222–238
Hujus tabula ea pars quæ pertinet ad modulos formæ 2^n, invenitur	239–240

The following is a specimen of the principal tables:—

$$p=19, \quad p-1=2 . 3^2.$$

Numeri.

I	0	1	2	3	4	5	6	7	8	9
		10	5	12	6	3	11	15	17	18
	9	14	7	13	16	8	4	2	1	

Indices.

N	0	1	2	3	4	5	6	7	8	9
		18	17	5	16	2	4	12	15	10
1	1	6	3	13	11	7	14	8	9	

where the first table gives the values of the powers of the prime root 10 (that 10 is the root appears by its index being given as =1) to the modulus 19, viz. $10^1 \equiv 10$, $10^2 \equiv 5$, $10^3 \equiv 12$, &c.; and the second table gives the index of the power to which the same prime root must be raised in order that it may be to the modulus 19 congruent with a given number, thus $10^{18} \equiv 1$, $10^{17} \equiv 2$, $10^5 \equiv 3$, &c. The units of the index or number, as the case may be, are contained in the top line of the table, and the tens or hundreds and tens in the left-hand column.

21. There is given,

Jacobi, Crelle, t. xxx. pp. 181, 182, a table of m' for the argument m, such that

$$1+g^m \equiv g^{m'} \text{ (mod. } p.\text{)}, \quad p=7 \text{ to } 103, \text{ and } m=0 \text{ to } 102.$$

A specimen is

p	7	11	13	17	19	23	29	31	37 . . . to 103
g	3	2	6	10	10	10	19	17	5
m									
11	.	.	6	4	7	*	27	21	34

for instance, $p=19$, $1+10^{11} \equiv 10^{17}$ (mod. 19).

Jacobi remarks that this table was calculated for him by his class during the winter course of 1836–37; and that, by means of the since-published 'Canon Arithmeticus,' the same might easily be extended to all primes under 1000. In fact for any such number p, putting any number of the table "Indices" $=m$, the next following number of the table gives the value of m'.

22. We have next in **Reuschle's** Memoir (*ante*, No. 15) the following relating to prime roots

C. Tafeln für primitive Wurzeln und Hauptexponenten, oder V. erweiterte und bereicherte Burkhardtsche Tafel, pp. 41–61, being divided into three parts; viz. these are

a. Table of the Hauptexponenten of the six roots 10, 5, 2, 6, 3, 7 for all prime numbers of the first 1000, together with the least primitive root of each of these numbers (pp, 42–46).

A specimen is as follows:—

		10		5		2		6		3		7		w
p	$p-1$	e	n	e	n	e	n	e	n	e	n	e	n	
53	$2^2.13$	13	4	52	1	52	1	26	2	52	1	26	2	2

where e is the Haupt-exponent or indicatrix of the root (10, 5, 2, 6, 3, 7, as the case may be), $n=\dfrac{p-1}{e}$, w the least primitive root; thus

$$p=53, \quad 10^{13} \equiv 1, \quad 5^{52} \equiv 1, \quad 2^{52} \equiv 1$$

(2 being accordingly the least prime root),

$$6^{26} \equiv 1, \quad 3^{52} \equiv 1, \quad 7^{26} \equiv 1.$$

The number w of the last column is the least primitive root; it is, of course, not always (as in the present case) one of the numbers 10, 5, 2, 6, 3, 7 to which the table relates: the first exception is $p=191$, $w=19$, the highest value of w being $w=21$ corresponding to $p=409$.

b. The like table for the roots 10 and 2 for all prime numbers from 1000 to 5000, together with as convenient as possible a prime root (and in some cases two prime roots) for each such number (pp. 47–53).

A specimen is:—

		10		2		
p	$p-1$	e	n	e	n	w
1289	$2^3.7.23$	92	14	161	8	6,11

viz. here mod. 1289, $10^{92} \equiv 1$, $2^{161} \equiv 1$; and two prime roots are 6, 11. We have thus by the present tables a prime root for every prime number not exceeding 5000.

c. The like table for the root 10 for all prime numbers between 5000 and 15000 (no column for w, nor any prime root given), pp. 53-61.

A specimen is

p	$p-1$	e	n
9859	2.3.31.53	3286	3

viz. mod. 9859 we have $10^{3286}\equiv1$. But in a large number of cases we have $n=1$, and therefore 10 a prime root. For example,

9887	2.4983	9886	1.

23. For a composite number n, if $N=\varpi(n)$ be the number of integers less than n and prime to it, than if x be any number less than n and prime to it, we have $x^N\equiv1$ (mod. n). But we have in this case no analogue of a prime root—there is no number x, such that its several powers $x^1, x^2, \ldots\ldots x^{N-1}$ (mod. n) are all different from unity; or, what is the same thing, there is for each value of x some submultiple of N, say N′, such that $x^{N'}\equiv1$ (mod. n). And these several numbers N′ have a least common multiple I, which is not $=$N, but is a submultiple of N; and this being so, then for all the several values of x, I is said to be the maximum indicator. For instance, $n=12$, $N=\varpi(n)$; the numbers less than 12 and prime to it are 1, 5, 7, 11. We have (mod. 12) $1^1\equiv1$, $5^2\equiv1$, $7^2\equiv1$, $11^2=1$, or the values of N′ are 1, 2, 2, 2; their least common multiple is 2, and we have accordingly $I=2$: viz. $x^2\equiv1$ (mod. 12) has the $\varpi(12)$ roots 1, 5, 7, 11. So $n=24$, $\varpi(n)=8$; the maximum indicator I is in this case also $=2$.

A table of the maximum indicator $n=1$ to 1000 is given

Cauchy, Exer. d'Analyse &c. t. ii. (1841), pp. 36–40, contained in the "Mémoire sur la résolution des équations indeterminées du premier degré en nombres entiers," pp. 1–40.

24. It thus appears that for a composite number n, the $\varpi(n)$ numbers less than n and prime to it cannot be expressed as $\equiv$ (mod. n) to the power of a single root; but for the expression of them it is necessary to employ two or more roots. A small table, $n=1$ to 50, is given

Cayley, Specimen Table $M\equiv a^\alpha b^\beta$ (mod. N) for any prime or composite modulus; Quart. Math. Journ. t. ix. (1867), pp. 95, 96, and folding sheet.

A specimen is

Nos.	12
roots	5, 7
Ind.	2, 2
M.I.	2
ϕ	4
1	0, 0
2	
3	
4	
5	1, 0
6	
7	0, 1
8	
9	
10	
11	1, 1

viz. for the modulus 12 the roots are 5, 7, having respectively the indicators 2, 2, viz. $5^2 \equiv 1$ (mod. 12), $7^2 \equiv 1$ (mod. 12). Hence also the maximum indicator is $=2$. $\phi\big(=\varpi(n)\big)=4$ is the number of integers less than 12 and prime to it, viz. these are 1, 5, 7, 11, which in terms of the roots 5, 7 and to mod. 12 are respectively $\equiv 5^0.7^0, 5^1.7^0, 5^0.7^1$, and $5^1.7^1$.

25. *Quadratic Residues.*—In regard to a given prime number p, a number N is or is not a quadratic residue according as the index of N is even or odd, viz. g being a prime root and $N \equiv g^{\alpha}$, then according as α is even or odd. But the quadratic residues can, of course, be obtained directly without the consideration of prime roots.

A small table, $p=3$ to 97 and $N=-1$ and (prime values) 3 to 97, is given **Gauss,** Disquisitiones Arithmeticæ, 1801; Table II. (Werke, t. i. p. 469): I notice here a misprint in the top line; it should be $-1, +2, +3$, &c., instead of $1, +2, +3$, &c.; the -1 is printed correctly in p. 499 of the French translation 'Recherches Arithmétiques,' Paris, 1807.

A specimen is

	−1	+2	+3	+5	+7	+11	+13	+17	+19	+23	&c.
19				–	–	–		–	–	–	

viz. $-1, 2, 3, 13$ are not, 5, 7, 11, 17 &c. are residues of 19. The residues taken positively and less than 19 are, in fact, 1, 4, 5, 6, 7, 11, 16, 17.

The same table carried from $p=3$ to 503, and prime values $N=3$ to 997, is given

Gauss, Werke, t. ii. pp. 400–409. Specimen is

	2	3	5	7	11	13	17	19	23	&c.
19			–	–	–		–	–	–	

viz. the arrangement is the same, except only that the -1 column is omitted.

26. We have also by **Gauss**

Table III. Disquisitiones Arithmeticæ (Werke, t. i. p. 470), for the conversion into decimals of a vulgar fraction, denominator p or p^{μ}, not exceeding 100. The explanation is given in art. 314 *et seq.* of the same work.

But this table, carried to a greater extent, is given by **Gauss**, Werke, t. ii. pp. 412–434, "Tafel zur Verwandlung gemeiner Bruche mit Nennern aus dem ersten Tausend in Decimalbrüche;" viz. the denominators are here primes or powers of primes, p^{μ} up to 997.

To explain the table, consider a modulus p^{μ} (where μ may be $=1$); if 10 is not a prime root of p^{μ}, consider a prime root r, which is such that $r^e 10 \equiv$ (mod. p^{μ}), e being a submultiple of $p^{\mu-1}(p-1)$; say we have $ef=p^{\mu-1}(p-1)$, then $10^f \equiv 1$ (mod. p^{μ}). Consider any fraction $\frac{N}{p^{\mu}}$, then we may write $N \equiv r^{kl+l}$ (mod. p^{μ}) k from 0 to $f-1$, and l from 0 to $e-1$, $\equiv 10^k r^l$, and consequently $\frac{N}{p^{\mu}}$ and $\frac{10^k r^l}{p^{\mu}}$ have the same mantissa (decimal part regarded as an integer); hence, in order to know the mantissa of every fraction whatever of $\frac{N}{p^{\mu}}$, it is sufficient to know the mantissa of $\frac{rl}{p^{\mu}}$, that is the mantissæ of $\frac{1}{p^{\mu}}, \frac{r}{p^{\mu}}, \frac{r^2}{p^{\mu}} \ldots \frac{r^{e-1}}{p^{\mu}}$, or, what is the same thing, the mantissæ of $\frac{10}{p^{\mu}}, \frac{10r}{p^{\mu}}, \ldots \frac{10r^{e-1}}{p^{\mu}}$.

For instance, $p^{\mu}=11$, $10^2\equiv1$ (mod. 11), whence $f=2$, $e=5$; and taking $r=2$, we have $10\equiv r^5$ (mod. 11).

The required mantissæ, denoted in the table by

$$\begin{array}{ccccc} (0) & (1) & (2) & (3) & (4) \end{array}$$

are those of

$$\frac{10}{11}, \frac{10\,.\,2}{11}, \frac{10\,.\,2^2}{11}, \frac{10\,.\,2^3}{11}, \frac{10\,.\,2^4}{11},$$

viz. these fractions are respectively=

$$\begin{array}{ccccc} (0) & (1) & (2) & (3) & (4) \\ \cdot9090\,.\,., & 1\cdot8181\,.\,., & 3\cdot6363\,.\,., & 7\cdot2727\,.\,., & 14\cdot5454\,.\,.; \end{array}$$

or their mantissæ are 90, 81, 63, 27, 54.

And we accordingly have as a specimen

11 | (1)..81 (2)..63 (3)...27 (4)..54. (0)90.

Or again, as another specimen, $r=2$:—

27 | (1)...740 (2)..481 (3)..962 (4)..925 (5)..851 (0)..370.

The table in this form extends to $p^{\mu}=463$; the values of r (not given in the body of the table) are annexed, p. 420.

In the latter part of the table $p^{\mu}=467$ to 997, we have only the mantissæ of $\frac{100}{p^{\mu}}$. A specimen is

547	1828153564	8994515539	3053016453	3820840950
	6398537477	1480804387	5685557586	8372943327
	2394881170	0182815356,		

viz. the fraction $\frac{100}{546}=\cdot182815\ldots$ has a period of 91, $=\frac{1}{6}$ 546, figures.

Art. 3. [F. 13. *The Pellian Equation.*]

27. The Pellian equation is $y^2=ax^2+1$, a being a given integer number, which is not a square (or rather, if it be, the solution is only $y=1$, $x=0$), and x, y being numbers to be determined: what is required is the least values of x, y, since these, being known, all other values can be found. A small table $a=2$ to 68 is given.

Euler, Op. Arith. Coll. t. i. p. 8. The Memoir is "Solutio problematum Diophanteorum per numeros integros," pp. 4–10, 1732–33. The form of the table is

a	$x(=p)$	$y(=q)$
2	2	3
3	1	2
5	4	9
⋮	⋮	⋮
68	4	33.

Even here, for some of the values of a, the values of x, y are extremely large; thus $a=61$, $x=226,153,980$, $y=1,766,399,049$.

And probably tables of a like extent may be found elsewhere; in particular a table of the solution of $y^2=ax^2\pm1$ ($-$ when the value of a is such that there is a solution of $y^2=ax^2-1$, and $+$ for other values of a), $a=2$ to 135 is given, **Legendre**, 'Théorie des Nombres,' 2nd ed. 1808, in the Table X. (one page) at the end of the work. For the before-mentioned number 61 the equation is $y^2=61\ x^2-1$, and the values are $x=3805$, $y=29718$; much smaller than Euler's values for the equation $y^2=61\ x^2+1$.

28. The most extensive table, however, is

Degen, "Canon Pellianus, sive Tabula simplicissimam equationis celebratissimæ: $y^2=ax^2+1$, solutionem, pro singulis numeri dati valoribus ab 1 usque ad 1000 in numeris rationalibus, iisdemque integris exhibens." Auctore Carolo Ferdinando Degen. Hafn (Copenhagen) apud Gerhardum Bonnarum, 1817. 8vo, pp. iv to xxiv and 1 to 112.

The first table (pp. 3-106) is entitled as "Tabula I. Solutionem Equationis $y^2-ax^2-1=0$ exhibens." It in fact also gives the expression of $\sqrt{a}$ as a continued fraction; thus a specimen is

209	14	2	5	3	(2)
	1	13	5	8	11
	3220				
	46551				

Here the first line gives the continued fraction, viz.

$$\sqrt{209}=14+\frac{1}{2}+\frac{1}{5}+\frac{1}{3}+\frac{1}{2}+\frac{1}{3}+\frac{1}{5}+\frac{1}{2}+\frac{1}{28}+\frac{1}{2}+\&c.,$$

the period being (2, 5, 3, 2, 3, 5, 2) indicated by 2, 5, 3 (2). [The number of terms in the period is here odd, but it may be even; for instance, the period (1, 1, 5, 5, 1, 1) is indicated by 1, 1 (5, 5)].

The second line contains auxiliary numbers presenting themselves in the process; thus $R^2=239$ we have $R=14+\frac{1}{\alpha}$,

$$\alpha=\frac{1}{R-14}=\frac{1(R+14)}{209-14^2}=\frac{R+14}{13}=2+\frac{1}{\beta},$$

$$\beta=\frac{13}{R-12}=\frac{13(R+12)}{209-12^2}=\frac{R+12}{5}=5+\frac{1}{\gamma},$$

$$\gamma=\frac{5}{R-13}=\frac{5(R+13}{209-13^2}=\frac{R+13}{8}=3+\frac{1}{\delta},$$

&c.,

where the second line 1, 13, 5 ... shows the numerical factors of the third column. The value of this second line as a result is not very obvious.

The third line gives x, and the fourth line y.

29. The second table, pp. 109-112, is entitled "Tabula II. Solutionem æquationis $y^2-ax^2+1=0$ quotiescunque valor ipsius a talem admiserat, exhibens;" viz. it is remarked that this is only possible (but see *infrà*) for those

values of a which in Table I. correspond to a period of an even number of terms, as shown by two equal numbers in brackets; thus $a=13$, the period of $\sqrt{13}$ given in Table I. is (1, 1, 1, 1) as shown by the top line 3, 1 (1, 1), and accordingly 13 is one of the numbers in Table II.; and we have there

$$13\ \begin{array}{|l}\hline 5\\ 18;\\ \hline\end{array}\quad\text{or take another specimen,}\quad 241\ \begin{array}{|l}\hline 4574225\\ 71011068;\\ \hline\end{array}$$

viz. the first line gives the value of x, and the second line the value of y (least values), for which $y^2-ax^2=-1$.

It is to be noticed that $a=2$ and $a=5$, for which we have obviously the solutions ($x=1, y=1$) and ($x=1, y=2$) respectively, are exceptional numbers not satisfying the test above referred to; and (apparently for this reason) the values in question, 2 and 5, are omitted from the table.

30. **Cayley**, "Table des plus petites solutions impaires de l'équation $x^2-Dy^2=\pm 4, D\equiv 5$ (mod. 8)." Crelle, t. liii. (1857), page 371 (one page).

It is, as regards the theory of quadratic forms, important to know whether for a given value of D($\equiv 5$, mod. 8) there does or does not exist a solution in odd numbers of the equation, $x^2-Dy^2=4$. As remarked in the paper, "Note sur l'équation $x^2-Dy^2=\pm 4, D\equiv 5$ (mod. 8)," pp. 369–371, this can be determined for values of D of the form in question up to $D=997$ by means of Degen's Table; and the solutions, when they exist, of the equation $x^2-Dy^2=4$, as also of the equation $x^2-Dy^2=-4$, obtained up to the same value of D. Observe that when the equation $x^2-Dy^2=-4$ is possible, the equation $x^2-Dy^2=4$ is also possible, and that its least solution is obtained very readily from that of the other equation; it is therefore sufficient to tabulate the solution of $x^2-Dy^2=\pm 4$, the sign being − when the corresponding equation is possible, and being in other cases +. Hence the form of the Table, viz. as a specimen we have

D	±	x	y
757		imposs.	
765	+	83	3
773	−	139	5
781		imposs.	
⋮			

that is, $D=757$ or 781, there is no solution of either $x^2-Dy^2=+4$ or $=-4$; $D=765$, there is a solution $x=83$, $y=3$ of $x^2-Dy^2=+4$, but none of $x^2-Dy^2=-4$; $D=773$, there is a solution $x=139$, $y=5$ of $x^2-Dy^2=-4$, and therefore also a solution of $x^2-Dy^2=+4$; and so in other cases.

Art. 4. [F. 14. *Partitions.*]

31. The problem of Partitions is closely connected with that of Derivations. Thus if it be asked in how many ways can the number n be expressed as a sum of three parts, the parts being 0, 1, 2, 3, and each part being repeatable an indefinite number of times, it is clear that n is at most $=9$, and that for the values of m, $=0, 1 \ldots 9$ shown by the top line of the annexed table, the number of partitions has the values shown by the bottom line thereof;—

0	1	2	3	4	5	6	7	8	9
a^3	a^2b	a^2c ab^2	a^2d abc b^3	abd ac^2 b^2c	acd b^2d bc^2	ad^2 bcd c^3	bd^2 c^2d	cd^2	d^3
1	1	2	3	3	3	3	2	1	1

But taking a, b, c, d to stand for 0, 1, 2, 3 respectively, the actual partitions of the required form are exhibited by the literal terms of the table (these being obtained, each column from the preceding one, by the method of derivations, or say by the rule of the last and last but one), and the numbers of the bottom line are simply the number of terms in the several columns respectively.

32. A set of such literal tables, say of tables $\left(\begin{smallmatrix} a, & b, & c & \dots & k \\ =0, & 1, & 2 & \dots & m \end{smallmatrix}\right)^n$, for different values of n and m (where the number of letters is $=m+1$), would be extremely interesting and valuable. The tables for a given value of m and for different values of n are, it is clear, the proper foundation of the theory of the binary quantic $(a, b, c \dots k \between x, 1)^m$, which corresponds to such value of m. Prof. Cayley regrets that he has not in his covariant tables given in every case the complete series of literal terms (viz. the literal terms which have zero coefficients are, for the most part, though not always, omitted in the expressions of the several covariants).

33. But the question at present is as to the *number* of terms in a column, that is, as to the number of the partitions of a given form: the analytical theory has been investigated by Euler and others. The expression for the number of partitions is usually obtained as = coefficient of x^n in the development, in ascending powers of x, of a given rational function of x: for instance, if there is no limitation as to the number of the parts, but if the parts are 1, 2, 3, m (viz. a part may have any value not exceeding m), each part being repeatable an indefinite number of times, then

$$\text{Number of partitions of } n = \text{coefficient } x^n \text{ in } \frac{1}{(1-x)(1-x^2)(1-x^3)\,.\,.(1-x^m)},$$

and we can, by actual development, obtain for any given values of m, n the number of partitions.

These have been tabulated $m=1, 2, \dots 20$, and $m=\infty$ (viz. there is in this case no limit as to the largest part), and $n=1$ to 59,

Euler, Op. Arith. Coll. t. i. pp. 97–101 (given in the paper "De Partitione Numerorum," pp. 73–101, 1750); heading is "Tabula indicans quot variis modis numerus n e numeris 1, 2, 3, 4 ... m per additionem exhibi potest, seu exhibens valores formulæ $n^{(m)}$." The successive lines are, in fact, the coefficients of the several powers $x^0, x^1 \,.\,.\, x^9$ in the expansions of the functions

$$\frac{1}{1-x}, \frac{1}{1-x\,.\,1-x^2}, \dots \frac{1}{1-x\,.\,1-x^2 \dots 1-x^{20}}.$$

34. The generating function for any given value of m is, it is clear, $=\frac{1}{1-x^m}$ into that for the next preceding value of m, and it thus appears how each line of the table is calculated from that which precedes it. The auxiliary numbers are *printed*; thus a specimen is

Valores numeri *n*.

m	0	1	2	3	4	5	6	7	8	9	10
					1	1	2	3	5	6	9
4	1	1	2	3	5	6	9	11	15	18	23
		.	.	.	.	1	1	2	3	5	7
5	1	1	2	3	5	7	10	13	18	23	30

viz. suppose the numbers in the second 4-line known: then simply moving these each five steps onward we have the (auxiliary) numbers of the first 5-line; and thence by a mere addition the required series of numbers shown by the second 5-line. And similarly from this is obtained the second 6-line, and so on.

35. More extensive tables are contained in the memoir

Marsano, "Sulle legge delle derivate generale delle funzione di funzione et sulla teoria delle forme di partizione dei numeri intieri" (4°, Genova, 1870), pp. 1–281; and three tables paged separately, described merely as "Tavoli dei numeri $C_{q,r}$, $S_{q,e}$, $S'_{q,e}$ citate nel testo colle indicazioni di Tavole I., II., III., ai n^{i} 77, 79, 81;" viz. the reader is referred to these articles for the explanations of what the tabulated functions are; and there is not even then any explicit statement, but the investigation itself has to be studied to make out what the tables are. It is, in fact, easier to make this out from the tables themselves; the explanation is as follows:—

Table I. (16 pages) is, in fact, Euler's table, showing in how many ways the number *n* can be made up with the parts 1, 2, 3 . . . *m*; but the extent is greater, viz. *n* is from 1 to 103, and *m* from 1 to 102. The auxiliary numbers given in Euler's table are omitted, as also certain numbers which occur in each successive line; thus a specimen is

$n=$	1	2	3	4	5	6	7	8	9	10	&c.
$C_{0,n}$	1	0	0	0	0	0	0	0	0	0	
$C_{1,n}$		1	1	1	1	1	1	1	1	1	
$C_{2,n}$			2	2	3	3	4	4	5	5	
$C_{3,n}$				3	4	5	7	8	10	12	
$C_{4,n}$					5	6	9	11	15	18	
&c.											

where the line $C_{4,n}$ (ways of making up *n* with the parts 1, 2, 3, 4) is 1, 1, 2, 3, 5, 6, 9, 11, 15, 18, &c., viz. we read from the corner diagonally downwards as far as the 5, and then horizontally along the line: this saves a large number of figures. The table is printed in ordinary quarto pages, which are taken to come in in tiers of seven, five, and three pages one under the other, as shown by a prefixed diagram; and the necessity of a large folding plate is thus avoided.

The successive lines give, in fact, the coefficients in the expansions of

$$\frac{1}{1-x}, \frac{1}{1-x\,.\,1-x^2}, \frac{1}{1-x\,.\,1-x^2\,.\,1-x^3} \cdots \frac{1}{1-x\,.\,1-x^2 \ldots 1-x^{102}},$$

each expanded as far as x^{103}.

Table II. (6 pages). The successive lines give the coefficients in the expansions of

$$S, \frac{S}{1-x}, \frac{S}{1-x\,.\,1-x^2} \cdots \frac{S}{1-x\,.\,1-x^2 \ldots .\, 1-x^{35}},$$

where
$$S = \frac{1}{(1-x)(1-x^2)(1-x^3)} \ldots .\ \text{ad. inf.},$$

each expanded as far as x^{53}, and further continued as regards the first ten lines, that is, the expansions of

$$S, \frac{S}{1-x}, \frac{S}{1-x\,.\,1-x^2} \cdots \frac{S}{1-x\,.\,1-x^2 \ldots .\, 1-x^{9}},$$

each as far as x^{107}.

Table III. (2 pages). The successive lines give the coefficients in the expansions of

$$S^2, \frac{S^2}{1-x}, \frac{S^2}{1-x\,.\,1-x^2} \cdots \frac{S}{1-x\,.\,1-x^2 \ldots .\, 1-x^{5}},$$

each expanded as far as x^{66}.

36. As regards Tables II. and III., the analytical explanations have been given in the first instance; but it is easy to see that the tables give numbers of partitions. Thus in table II. the second line gives the coefficients in the development of

$$\frac{1}{(1-x)^2(1-x^2)(1-x^3) \ldots .};$$

viz. these are 1, 2, 4, 7, 12, 19, 30. . . ., being the number of ways in which the numbers 0, 1, 2, 3, 4, &c. respectively can be made up with the parts 1, 1′, 2, 3, 4, &c.; thus

	Partitions.	No. =
1	1 1′	2
2	2 1, 1 1, 1′ 1′, 1′	4
3	3 2, 1 2, 1′ 1, 1, 1 1, 1, 1′ 1, 1′, 1′ 1′, 1′, 1′	7
&c.		&c.

and similarly the third line shows the number of ways in which these numbers respectively can be made up with the parts 1, 1′, 2, 2′, 3, 4, 5, &c; the fourth line with the parts 1, 1′, 2, 2′, 3, 3′, 4, 5, &c.; and so on.

And in like manner in Table III. the first line shows the number of ways when the parts are 1, 1′, 2, 2′, 3, 3′ . . . .; the second line when they are 1, 1′, 1″, 2, 2′, 3, 3′ . . . .; the third when they are 1, 1′, 1″, 2, 2′ 2″, 3, 3′, &c.; and so on.

It is clear that the series of tables might be continued indefinitely, viz. there might be a table IV. giving the developments of

$$S^3, \frac{S^3}{1-x}, \frac{S^3}{1-x\,.\,1-x^2}, \text{ and so on.}$$

An interesting table would be one composed of the first lines of the above series, viz. a table giving in its successive lines the developments of S, S^2, S^3, S^4, &c.

There are throughout the work a large number of numerical results given in a quasi-tabular form; but the collection of these, with independent explanations of the significations of the tabulated numbers, would be a task of considerable labour.

Art. 5. [F. 15. *Quadratic forms* a^2+b^2 *&c., and Partitions of Numbers into squares, cubes, and biquadrates.*]

37. The forms here referred to present themselves in the various complex theories, thus $N=a^2+b^2$, $=(a+bi)(a-bi)$; this means that in the theory of the complex numbers $a+bi$ (a and b integers) N is not a prime, but a composite number. It is well known that an ordinary prime number $\equiv 3$, mod. 4, is not expressible as a sum a^2+b^2, being, in fact, a prime in the complex theory as well as in the ordinary one, but that an ordinary prime number $\equiv 1$, mod. 4, is (in one way only) $=a^2+b^2$; so that it is in the complex theory a composite number. A number whose prime factors are each of them $\equiv 1$, mod. 4, or which contains, if at all, an even number of times any prime factor $\equiv 3$, mod. 4, can be expressed in a variety of ways in the form a^2+b^2; but these are all easily deducible from the expressions in the form in question of its several factors $\equiv 1$, mod. 4, so that the required table is a table of the form $p=a^2+b^2$, p an ordinary prime number $\equiv 1$, mod. 4: a and b are one of them odd, the other even; and to render the decomposition definite a is taken to be odd.

$p=a^2+b^2$; viz. decomposition of the primes of the form $4n+1$ into the sum of two squares, a table extending from $p=5$ to 11981 (calculated by *Zornow*) is given

Jacobi, Crelle, t. xxx. (1846), pp. 174–176.

This is carried by Reuschle, as presently mentioned, up to $p=24917$. Reuschle notices that $2713=3^2+52^2$ is omitted, also $6997=39^2+74^2$, and that 8609 should be $=47^2+80^2$.

38. Similarly primes of the form $6n+1$ are expressible in the form $p=a^2+3b^2$. (Observe that ω being an imaginary cube root of unity, this is connected with $p'=(a+b\omega)(a+b\omega^2)$, $=a^2-ab+b^2$, viz. we have $4p'=(2a-b)^2+3b^2$; or the form a^2+3b^2 is connected with the theory of the complex numbers composed of the cube roots of unity.)

$p=a^2+3b^2$; viz. decomposition of the primes of the form $6n+1$ into the form a^2+3b^2. A table extending from $p=7$ to 12007 (calculated also by *Zornow*) is given

Jacobi, Crelle, t. xxx. (1846), *ut suprà*, pp. 177–179.

This is carried by Reuschle up to $p=13369$, and for certain higher numbers up 49999, as presently mentioned. Reuschle observes that $6427=80^2+3\,.\,3^2$ is by accident omitted, and that 6481 should be $=41^2+3\,.\,40^2$.

39. Again, primes of the form $8n+1$ are expressible in the form $p=a^2+2b^2$ (or say $=c^2+2d^2$), the theory being connected with that of the complex numbers composed with the 8th roots of unity (fourth root of -1, $=\frac{1+i}{\sqrt{2}}$).

$p=c^2+2d^2$; viz. decomposition of primes of the form $8n+1$ into the form c^2+2d^2. A table extending from $p=16$ to 5943 (extracted from a MS. table calculated by *Struve*) is given

Jacobi, Crelle, t. xxx. (1846), *ut suprà*, p. 180.

This is carried by Reuschle up to $p=12377$, and for certain higher numbers up to 24889, as presently mentioned.

40. Reuschle's tables of the forms in question are contained in the work:—

Reuschle, 'Mathematische Abhandlung &c.' (see *ante* No. 15), under the heading "B. Tafeln zur Zerlegung der Primzahlen in Quadrate" (pp. 22–41). They are as follows:—

Table III. for the primes $6n+1$.

First part gives $p=A^2+3B^2$ and $4p=L^2+27M^2$, from $p=7$ to 5743.

Table gives A, B, L, M; and those numbers which have 10 for a cubic residue are distinguished by an asterisk.

A specimen is

p	A	B	L	M
37*	5	2	11	1

;

viz. $37=5^2+3.2^2$, $148=11^2+27.1^2$; and asterisk shows that $x^3\equiv+10$ (mod. 37) is possible [in fact $34^3\equiv 10$ (mod. 37)].

Second part gives $p=A^2+3B^2$ only, from $p=5749$ to 13669.

Table gives A, B and asterisk as before.

Third part gives $p=A^2+3B^2$, but only for those values of p which have 10 for a cubic residue (viz. for which $x^3\equiv 10$ (mod. p) is possible), from $p=13689$ to 49999.

Table gives A, B; asterisk, as being unnecessary, is not inserted.

Table IV. for the primes $4n+1$ in the form A^2+B^2, and for those which are also $8n+1$ in the form C^2+2D^2.

First part gives $p=A^2+B^2$, $=C^2+2D^2$, from $p=5$ to 12377.

Table gives A, B, C, D; and those numbers which have 10 for a biquadratic residue ($x^4\equiv 10$ (mod. p) possible) are distinguished by an asterisk; those which have also 10 for an octic residue ($x^8\equiv 10$ (mod. p) possible) by a double asterisk.

A specimen is

p	A	B	C	D
229	15	2	—	—
233	13	8	15	2
241**	15	4	13	6

Second part gives $p=A^2+B^2$, from $p=12401$ to 24917 for all those values of p which have 10 for a biquadratic residue ($x^4\equiv 10$ (mod. p) possible).

Table gives A, B; and those values of p which have 10 for an octic residue, $x^8\equiv 10$ (mod. p) possible, are distinguished by an asterisk.

Third part gives $p=C^2+2D^2$, from $p=12641$ to 24889 for all those values of p which have 10 for a biquadratic residue.

Table gives C, D; and those values of p which have 10 as an octic residue are distinguished by an asterisk.

41. A table by **Zornow**, Crelle, t. xiv. 1835, pp. 279, 280 (belong to Memoir 'De Compositione numerorum e Cubis integris positivis,' pp. 276–280), shows for the numbers 1 to 3000 the least number of cubes into which each of these numbers can be decomposed. Waring gave, without demonstration, the theorem that every number can be expressed as the sum of at most 9 cubes. The present table seems to show that 23 is the only number for which the number of cubes is $=9$ $(=2.2^3+7.1^3)$; that there are only fourteen numbers for which the number of cubes is $=8$, the largest of these

being 454; and hence that every number greater than 454 can be expressed as a sum of at most 7 cubes; and further, that every number greater than 2183 can be expressed as a sum of at most 6 cubes. A small subsidiary table (p. 276) shows that the number of numbers requiring 6 cubes gradually diminishes—*e. g.* between 12^3 and 13^3 there are seventy-five such numbers, but between 13^3 and 14^3 only sixty-four such numbers; and the author conjectures "that for numbers beyond a certain limit every number can be expressed as a sum of at most 5 cubes."

42. For the decomposition of a number into biquadrates we have

Bretschneider, "Tafeln fur die Zerlegung der Zahlen bis 4100 in Biquadrate." Crelle, t. xlvi. (1853), pp. 3–23.

Table I. gives the decompositions, thus:—

N	1^4	2^4	3^4	4^4	5^4
696	6	1	2	2	
	3	2	5	1	
	0	3	8		

viz. $696=6\,.\,1^4+1\,.\,2^4+2\,.\,3^4+2\,.\,4^4$, &c.

And Table II. enumerates the numbers which are sums of at least 2, 3, 4 ....19 biquadrates; and there is at the end a summary showing for the first 4100 numbers how many numbers there are of these several forms respectively: 28 numbers are each of them a sum of 2 biquadrates, 75 a sum of 3, ... 7 a sum of 19 biquadrates. The seven numbers, each of them a sum of 19 biquadrates, are 79, 159, 239, 319, 399, 479, 559.

Art. 6. [F. 16. *Binary*, *Ternary*, *&c. quadratic and higher forms.*]

43. Euler worked with the quadratic forms $ax^2 \pm cy^2$ (p and q integers), particularly in regard to the forms of the divisors of such numbers. It will be sufficient to refer to his memoir:—

Euler, "Theoremata circa divisores numerorum in hâc formâ $pa^2 \pm qb^2$ contentorum" (Op. Arith. Coll. pp. 35–61, 1744), containing fifty-nine theorems, exhibiting in a quasi-tabular form the linear forms of the divisors of such numbers. As a specimen:—

"Theorema 13. Numerorum in hâc formâ $a^2+76\,b^2$ contentorum divisores primi omnes sunt vel 2, vel 7, vel in unâ sex formularum

$$\begin{array}{ll} 28m+1, & 28m+11, \\ 28m+9, & 28m+15, \\ 28m+25, & 28m+23, \end{array}$$

seu in unâ harum trium

$$\begin{array}{l} 14m+1, \\ 14m+9, \\ 14m+11 \end{array}$$

sunt contenti;" viz. the forms are the three $14m+1$, $14m+9$, $14m+11$.

But Euler did not consider, or if at all very slightly, the trinomial forms $ax^2+bxy+cy^2$, nor attempt the theory of the reduction of such forms. This was first done by Lagrange in the memoir

Lagrange, 'Mém. de Berlin,' 1773. And the theory is reproduced

Legendre, 'Théorie des Nombres.' Paris, 1st edit. 1798; 2nd edit. 1808, § 8, "Reduction de la formule $Ly^2+Myz+Nz^2$ à l'expression la plus simple" (2nd ed. pp. 61–67).

44. But the classification of quadratic forms, as established by Legendre, is defective as not taking account of the distinction between proper and improper equivalence; and the ulterior theory as to orders and genera, and the

composition of forms (although in the mean time established by Gauss), are not therein taken into account; for this reason the **Legendre's** Tables I. to VIII. relating to quadratic forms, given after p. 480 (thirty-two pages not numbered), are of comparatively little value, and it is not necessary to refer to them in detail.

The complete theory was established

Gauss, 'Disquisitiones Arithmeticæ,' 1801.

It is convenient to refer also to the following memoir

Lejeune Dirichlet, "Recherches sur diverses applications de l'Analyse à la théorie des Nombres," Crelle, t. xix. (1839), pp. 338, as giving a succinct statement of the principle of classification, and in particular a table of the characters of the genera of the properly primitive order, according to the four forms $D=PS^2$, $P\equiv1$ or 3 (mod. 4), and $D\equiv2PS^2$, $P\equiv1$ or 3 (mod. 4) of the determinant.

45. Tables of quadratic forms arranged on the Gaussian principle are given

Cayley, Crelle, t. lx. (1862), pp. 357–372; viz. the tables are—

Table I. des formes quadratiques binaires ayant pour déterminants les nombres négatifs depuis D= − jusqu'à D= −100. (Pp. 360–363.)

A specimen is

D	Classes.	α	β	δ	ϵ	$\delta\epsilon$	C*p*
=26	1, 0, 26	+				+	1
	3, −1, 9	+				+	g^2
	3, 1, 9	+				+	g^1
	5, 2, 6	−				−	g
	2, 0, 13	−				−	g^3
	5, −2, 6	−				−	g^5

where α, β denote, as there explained, the characters in regard to the odd prime factors of D; δ, ϵ, $\delta\epsilon$ those in regard to the numbers 4 and 8. The last column shows that the forms in the two genera respectively are 1, g^2, g^4 and g, g^3, g^5, where $g^6=1$, viz. the form g six times compounded, gives the principal form (1, 0, 26).

Table II. des formes quadratiques binaires ayant pour déterminants les nombres positifs non-carrés depuis D=2 jusqu'à D=99. (Pp. 364–369.)

The arrangement is the same, except that there is a column "Périodes" showing in an easily understood abbreviated form the period of each form. Thus D = 7, the period of the principal form (1, 0, −7), is given as 1, 2, −3, 1, 2, 1, −3, 2, 1, which represents the series of forms (1, 2, −3), (−3, 1, 2) (2, 1, −3), (−3, 2, 1).

Table III. des formes quadratiques binaires pour les treize déterminants négatifs irréguliers du premier millier. (Pp. 370–372.)

Arrangement the same as in Table I. It may be mentioned that the thirteen numbers, and the forms for the principal genus for these numbers, respectively are:—

−D=	Principal genus.
576, 580, 820, 900	$(1, e^2)(1, e_1{}^2)$
884	$(1, e^2)(1, i^2, i^4, i^6)$
243, 307, 339, 459, 675, 891	$(1, d, d^2)(1, d_1, d_1{}^2)$
755, 974	$(1, d, d^2)(1, d_1, d_1{}^2)(1, e^2)$.

where $d^3=d_1^3=1$, $e^4=e_1^4=1$, $i^8=1$, viz. $(1,e^2)(1,e_1^2)$ denotes four forms, $1, e^2, e_1^2, e^2e_1^2$; and so in the other cases.

46. **Gauss** must have computed quadratic forms to an enormous extent; but, for the reasons (rather amusing ones) mentioned in a letter of May 17, 1841, to Schumacher (quoted in Prof. Smith's Report on "The Theory of Numbers," Brit. Assoc. Report for 1862, p. 526), he did not preserve his results in detail, but only in the form appearing in the

"Tafel der Anzahl der Classen binärer quadratischer Formen," *Werke*, t. ii. pp. 451–475; see editor's remarks, pp. 497–499.

This relates almost entirely to negative determinants, only three quarters of p. 475 and p. 476 to positive ones; viz. for negative determinants it gives the number of genera and classes, as also the index of irregularity for the determinants of the hundreds 1 to 30, 43, 51, 61, 62, 63, 91 to 100, 117 to 120; then in a different arrangement for the thousands 1, 3 and 10, for the first 800 numbers of the forms $-(15n+7)$ and $-(15n+13)$; also for some very large numbers, and for positive determinants of the hundreds 1, 2, 3, 9, 10, and some others.

A specimen is

$$\begin{array}{rl}
 & \text{Centas I.} \\
\text{G II.} & (58)\ldots.(280) \\
1. & 5,\ 6,\ 8 \\
 & 9,\ 10,\ 12 \\
 & 13,\ 15,\ 16 \\
 & 18,\ 22,\ 25 \\
 & 28,\ 37,\ 58 \\
2. & 14,\ 17,\ 20 \\
 & 32,\ \&\text{c.} \\
\hline
\text{Summa} & 233\ldots.477 \\
\text{Irreg.} & 0\quad \text{Imp. } 74
\end{array}$$

viz. this shows (as regards the negative determinants 1 to 100) that the determinants belonging to G II. 1, viz. those which have two genera each of one class, are 5, 6, 8, 9, &c. (in all fifteen determinants); those belonging to G II. 2, viz. those which have two genera each of two classes, are 14, 17, 20, &c., and so on. The head numbers (58) .. (280) show the number of determinants, each having two genera, and the number of classes; thus,

$$\begin{array}{lrr}
\text{G II.} & 1\times15= & 15 \\
 & 2\times17= & 34 \\
 & 3\times17= & 51 \\
 & 4\times\ 6= & 24 \\
 & 5\times\ 2= & 10 \\
 & 6\times\ 1= & 6 \\
\hline
 & 58 & 140 \\
 & & \times\text{II} \\
 & & =280
\end{array}$$

and the bottom numbers show the total number of genera and of classes, thus.

$$\begin{array}{rrrr}
\text{G I.} & 17\times1= & 17 & 61 \\
\text{II.} & 58\times2= & 116 & 280 \\
\text{IV.} & 25\times4= & 100 & 136 \\
\hline
 & 100 & 233 & 477
\end{array}$$

viz. seventeen determinants, each of one genus, and together of sixty-one classes; fifty-eight determinants, each of two genera, and together of 280 classes; and twenty-five determinants, each of four genera, and together 136 classes, give in all 233 genera and 477 classes: these are exclusive of 74 classes belonging to the improperly primitive order; and the number of irregular determinants (in the first hundred) is $=0$.

The irregular determinants are indicated thus:—

243(*3*)
307(*3*) 339(*3*)
459(*)
576(*2*) 580(*2*)
675(*3*)
755(*3*)
891(*3*) 820(*2*) 900(*2*) 884(*2*) 974(*3*)
3 243, 307, 339, 459?, 675, 755, 891,
2 576, 589, 820, 884, 900, 974,

which is a notation not easily understood.

As regards the positive determinants, a specimen is

Centas I.
Excedunt determinantis
quadrati 10.
G I. .... (12)
1. 2, 5, 13
17, 29, 41
53, 61, 73
89, 97
3. 37

viz. in the first hundred the positive determinants having one genus of one class are 2, 5, 13, &c...(eleven in number); that having one genus of three classes is 37 (one in number), $11+1=12$. The irregular determinants, if any, are not distinguished.

47. *Binary cubic forms.*—The earliest table is

Arndt, "Tabelle der reducirten binären kubischen Formen und Klassen für alle negativen Determinanten $-D$ von $D=3$ bis $D=2000$." *Grünert's Archiv*, t. xxxi. 1858, pp. 369–448.

The memoir is a sequel to one in t. xvii. (1851). The binary cubic form (a, b, c, d) of determinant $-D\big(=(bc-ad)^2-4(b^2-ac)(c^2-bd)\big)$ is said to be reduced when its characteristic $\phi, =(A, B, C), =\big(2(b^2-ac), bc-ad, 2(c^2-bd)\big)$ is a reduced quadratic form, that is, when in regard to absolute values B is not $>\frac{1}{2}A$, C not $<A$.

A specimen is

D	Reduced forms with characters.	Classes.
44	(0, 1, 0, −11) (1, −1, −2, 0) (2, 0, 22 6, 2, 8)	(0, −1, 0, 11) (0, −2, ±1, 1)

Two subsidiary tables are given, pp. 351, 352, and 353–368.

48. It appeared suitable to remodel a part of this table in the manner made use of for quadratic forms in my tables above referred to, and it is accordingly divided into the three tables given

Cayley, Quart. Math. Journ. t. xi. (1871), where the notation &c. is explained, pp. 251–261; viz. these are:—

Table I. of the binary cubic forms, the determinants of which are the negative numbers $\equiv 0 \pmod{4}$ from -4 to -400 (pp. 251–258).

A specimen is

Det.	Classes.	Order.	Charact.	Comp.
$4-\times 11$.	$0,\ -1,\ \ 0,\ 11$	on	$1,\ \ 0,\ 11$	1
	$0,\ -2,\ -1,\ 1$	*pp pp*	$3,\ \ 1,\ 4$	d
	$0,\ -2,\ \ 1,\ 1$		$3,\ -1,\ 4$	d^2.

Table II. of the binary cubic forms the determinants of which (taken positively) are $\equiv 1 \pmod{4}$ from -3 to -99 [the original heading is here corrected]; and

Table III. of the binary cubic forms the determinants of which are the negative numbers -972, -1228, -1336, -1836, and -2700; viz. $-972 = 4\times -243, \ldots\ldots -2700 = 4\times -675$, where $-243 \ldots -675$ are the first six irregular numbers for quadric forms].

$4\times -675, = -2700$ is beyond the limits of Arndt's tables, and for this number the calculation had to be made anew; the table gives nine classes $(1, d, d^2)(1, d_1, d_1^{\,2})$ of the order *ip* on *pp*, but it is remarked that there may possibly be other cubic classes based on a non-primitive characteristic; the point was left unascertained.

49. The theory of ternary quadratic forms was discussed and partially established by Gauss in the 'Disquisitiones Arithmeticæ.' It is proper to recall that a ternary quadratic form is either determinate, viz. always positive, such as $x^2+y^2+z^2$, or always negative, such as $-x^2-y^2-z^2$; or else it is indeterminate, such as $x^2+y^2-z^2$. But as regards determinate forms, the negative ones are derived from the positive ones by simply reversing the signs of all the coefficients, so that it is sufficient to attend to the positive forms; and the two cases are practically positive forms (meaning thereby positive determinate forms) and indeterminate forms; but the theory for positive forms was first established completely, and so as to enable the formation of tables, in the work

Seeber, 'Ueber die Eigenschaften der positiven ternären quadratischen Formen' (4to, Freiburg, 1831),

which is reviewed by Gauss in the 'Gott. Gelehrten Anzeigen,' 1831, July 9 (see Gauss, Werke, t. ii. pp. 188–193). The author gives (pp. 220–243) tables "of the classes of positive ternary forms represented by means of the corresponding reduced forms" for the determinants 1 to 100. A specimen is

$$\text{Det. } 6 \qquad \begin{pmatrix} 1, & 1, & 2 \\ 0, & 0, & -1 \end{pmatrix}, \quad \begin{pmatrix} 1, & 1, & 2 \\ -1, & -1, & 0 \end{pmatrix},$$

$$\begin{array}{r} \text{Zugeordnete} \\ \text{Formen} \end{array} \begin{pmatrix} 8, & 8, & 3 \\ 0, & 0, & 8 \end{pmatrix}, \quad \begin{pmatrix} 7, & 7, & 4 \\ 4, & 4, & 2 \end{pmatrix},$$

where it is to be observed that Seeber admits odd coefficients for the terms in yz, zx, xy; viz. his

$$\begin{pmatrix} a, & b, & c \\ f, & g, & h \end{pmatrix} \text{ denotes } \quad ax^2+by^2+cz^2+fyz+gzx+hxy,$$

and his determinant is

$$4abc-af^2-bg^2-ch^2+fgh.$$

Also his adjoint form is

$$\begin{pmatrix} 4bc-f^2, & 4ca-g^2, & 4ab-h^2 \\ 2gh-4af, & 2hf-4bg, & 2fg-4ch \end{pmatrix}, = (4bc-f^2)x^2 \ldots\ldots + (2gh-4af)yz + \ldots\ldots$$

In the notation of the 'Disquisitiones Arithmeticæ,' followed by Eisenstein and others,

$$\begin{pmatrix} a, & b, & c \\ f, & g, & h \end{pmatrix} \text{ denotes } \quad ax^2+by^2+cz^2+2fyz+2gzx+2hxy\,;$$

the determinant is

$$= -(abc-af^2-bg^2-ch^2+2fgh),$$

a positive form having thus always a negative determinant. And the adjoint form is

$$-\begin{pmatrix} bc-f^2, & ca-g^2, & ab-h^2 \\ gh-af, & hf-bg, & fg-ch \end{pmatrix}, = -(bc-f^2)x^2 \qquad -2(gh-af)yz\ldots.$$

Hence Seeber's determinant is $= -4$ into that of Gauss, and his tables really extend between the values -1 and -25 of the Gaussian determinant.

50. Tables of greater extent, and in the better form just referred to, are given

Eisenstein, Crelle, t. xli. (1851), pp. 169–190; viz. these are

I. "Tabelle der eigentlich primitiven positiven ternaren Formen für alle negativen Determinanten von -1 bis -100" (pp. 169–185).

A specimen is

D	Anzahl.	Reducirte Formen fur $-$D.
10	3	$\begin{pmatrix} 1, & 1, & 10 \\ 0, & 0, & 0 \end{pmatrix}, \begin{pmatrix} 1, & 2, & 5 \\ 0, & 0, & 0 \end{pmatrix}, \begin{pmatrix} 2, & 2, & 3 \\ 0, & -1, & 0 \end{pmatrix}$ $\delta=8 \qquad \delta=4 \qquad \delta=4$

II. "Tabelle der *uneigentlich* primitiven positiven ternaren Formen für alle negativen Determinanten von -2 bis -100" (pp. 186–189).

A specimen is

D	Anzahl.	Reducirte Formen fur $-$D.
10	1	$\begin{pmatrix} 2, & 2, & 4 \\ 1, & 1, & 1 \end{pmatrix}$ $\delta=6.$

And there is given (p. 190) a table of the reduced forms for the determinant $-385 (= -5 \,.\, 7 \,.\, 11)$ (selected merely as a largish number with three factors); viz. there are in all fifty-nine forms, corresponding to values 1, 2, 4, 6, 8 of δ.

It may be remarked that δ denotes for any given form the number of ways in which this is linearly transformable into itself, this number being always 1, 2, 4, 6, 8, 12, or 24. The theory as to this and other points is explained in the memoir (pp. 141–168), and various subsidiary tables are contained therein and in the 'Anhang' (pp. 227–242); and there is given a small table relating to *indeterminate forms*, viz. this is

"C. Versuch einer Tabelle der nicht aquivalenten unbestimmten (indifferenten) ternären quadratischen Formen für die Determinanten ohne quadratischen Theiler unter 20" (pp. 239, 240).

A specimen is

D	Indifferente ternäre quadratische Formen.
10	$\begin{pmatrix} 0, & 1, & 10 \\ 0, & 0, & 1 \end{pmatrix} \quad \begin{pmatrix} 1, & 2, & -5 \\ 0, & 0, & 0 \end{pmatrix}$ $\begin{pmatrix} 0, & 0, & 10 \\ 0, & 0, & 1 \end{pmatrix}$

where, when the determinant is even, the forms in the second line are always improperly primitive forms.

Art. 7. [F. 17. *Complex Theories.*]

51. The theory of binary quadratic forms (a, b, c), with complex coefficients of the form $a+\beta i$ $(i=\sqrt{-1}$ as usual, α and β integers), has been studied by Lejeune Dirichlet, Prof. H. J. S. Smith, and possibly others; but no tables have, it is believed, been calculated. The calculations would be laborious; but tables of a small extent only would be a sufficient illustration of the theory, and would, it is thought, be of great interest.

The theory of complex numbers of the last-mentioned form $\alpha+\beta i$, or say of the numbers formed with the fourth root of unity, had previously been studied by Gauss; and the theory of the numbers formed with the cube roots of unity $(\alpha+\beta\omega,\ \omega^2+\omega+1=0,\ \alpha$ and β integers) was studied by Eisenstein; but the general theory of the numbers involving the nth roots of unity (n an odd prime) was first studied by Kummer. It will be sufficient to refer to his memoir,

Kummer, "Zur Theorie der complexen Zahlen," Berl. Monatsb. March 1845; and Crelle, t. xxxv. (1847), pp. 319–326; also "Ueber die Zerlegung der aus Wurzeln der Einheit gebildeten complexen Zahlen in ihre Primfactoren," same volume, pp. 327–367,

where the astonishing theory of "Ideal Complex Numbers" is established.

52. It may be recalled that, p being an odd prime, and ρ denoting a root of the equation $\rho^{p-1}+\rho^{p-2}\ldots+\rho+1=0$; then the numbers in question are those of the form $a+b\rho\ldots+k\rho^{n-2}$, where $(a, b\ldots k)$ are integers; or (what is in one point of view more, and in another less, general) if $\eta, \eta_1\ldots\eta_{e-1}$ are "periods" composed with the powers of ρ (e any factor of $p-1$), then the form considered is $a\eta+b\eta_1\ldots+h\eta_{e-1}$. For any value of p or e there is a corresponding complex theory. A number (real or complex) is in the complex theory prime or composite, according as it does not, or does, break up into factors of the form under consideration. For p a prime number under 23, if in the complex theory N is a prime, then any power of N (to fix the ideas say N^3) has no other factors than N or N^2; but if $p=23$ (and similarly for higher values of p), then N may be such that, for instance, N^3 has complex factors other than N or N^2 (for $p=23$, $N=47$ is the first value of N, viz. 47^3 has factors other than 47 and 47^2); say N^3 has a complex prime factor A, or we have $\sqrt[3]{A}$ as an ideal complex factor of N. Observe that by hypothesis N is not a perfect cube, viz. there is no complex number whose cube is $=A$. In the foregoing general statement, made by way of illustration only, all reference to the complex factors of unity is purposely omitted, and the statement must be understood as being subject to correction on this account.

What precedes is by way of introduction to the account of **Reuschle's** Tables (Berliner Monatsberichte, 1859–60), which give in the different complex theories $p=5, 7, 11, 13, 17, 19, 23, 29$ the complex factors of the decomposable real primes up to in some cases 1000.

It should be remarked that the form of a prime factor is to a certain extent indeterminate, as the factor can without injury be modified by affecting it with a complex factor of unity; but in the tables the choice of the representative form is made according to definite rules, which are fully explained, and which need not be here referred to.

53. The following synopsis is convenient:—

	Theory of the *p*th roots.	Form of real prime to mod $p \equiv$	No. of factors in complex theory.	Extent of table; all primes under	Equation of periods.
1859. pp. 488–491.	5	1	4	2500	$\alpha^4+\ldots\ldots+\alpha+1=0.$
		4	2(not tabulated)		$y^2+y-1=0.$
		2, 3	prime.		
694–697.	7	1	6	1000	$\alpha^6\ldots\ldots+\alpha+1=0.$
		6	3		$y^3+y^2-2y-1=0.$
		2, 4	2		$y^2+y+2=0.$
		3, 5	prime.		
1860. pp. 190–194.	11	1	10	1000	$\alpha^{10}\ldots\,.+\alpha+1=0.$
		10	5		$y^5+y^4-4y^3-3y^2+3y+1=0.$
		3, 4, 5, 9	2		$y^2+y+3=0.$
		2, 6, 7, 8	1		
194–199.	13	1	12	1000	$\alpha^{12}\ldots\ldots+\alpha+1=0.$
		12	6		$y^6+y^5-5y^4-4y^3+6y^2+3y-1=0.$
		3, 9	4		$y^4+y^3+2y^2-4y+3=0.$
		5, 8	3		$y^3+y^2-4y+1=0.$
		4, 10	2		$y^2+y-3=0.$
		2, 6, 7, 11	prime.		
714–719.	17	1	16	1000	$\alpha^{16}\ldots\,.+\alpha+1=0.$
		16	8		$y^8+y^7-7y^6-6y^5+15y^4+10y^3-10y^2-4y+1=0.$
		4, 13	4		$y^4+y^3-6y^2+1=0.$
		2, 8, 9, 15	2		$y^2+y-4=0.$
		3, 5, 6, 7, 11, 12, 14	prime.		
719–725.	19	1	18	1000	$\alpha^{18}\ldots\,.+\alpha+1=0.$
		18	9		$y^9+y^8-8y^7-7y^6+21y^5+15y^4-20y^3-10y^2+5y+1=0.$
		7, 11	6		$y^6+y^5+2y^4-8y^3-y^2+5y+7=0.$
		8, 12	3		$y^3+y^2-6y-7=0.$
		4, 5, 6, 9, 13, 17	2		$y^2+y+5=0.$
		2, 3, 10, 13, 14, 15	prime.		
725–729.	23	1	22	1000	$\alpha^{22}\ \ldots+\alpha+1=0.$
		22	11		$y^{11}+y^{10}-10y^9-9y^8+36y^7+28y^6-56y^5-35y^4+35y^3+15y^2-6y-1=0.$
		2, 3, 4, 6, 8, 9, 12, 13, 16, 18	2		$y^2+y+6=0.$
		? 5, 7, 10, 11, 14, 15, 17, 19, 20, 21	prime		
729–734.	29	1	28	1000	$\alpha^{28}\ldots\ldots+\alpha+1=0.$
		28	14		$y^{14}+y^{13}-13y^{12}-12y^{11}+66y^{10}+55y^9-165y^8-120y^7+210y^6+126y^5-126y^4-56y^3+28y^2+7y-1=0.$
		12, 17	7		$y^7+y^6-12y^5-7y^4+28y^3+14y^2-9+y+1=0.$
		7, 16, 20, 23, 24, 25	4		$y^4+y^3+4y^2+20y+23=0.$
		4, 5, 6, 9, 13, 22	2		$y^2+y-7=0.$
		2, 3, 8, 10, 11,	prime.		

The foregoing synopsis of Reuschle's tables in the 'Berliner Monatsberichte' was written previous to the publication of Reuschle's far more extensive work. It is allowed to remain, but some explanations which were given have been struck out, and were instead given in reference to the larger work.

Reuschle, "Tafeln complexer Primzahlen welche aus Wurzeln der Einheit gebildet sind." Berlin, 4° (1875), pp. iii–vi and 1–667.

This work (the mass of calculation is perfectly wonderful) relates to the roots of unity, the degree being any prime or composite number, as presently mentioned, having all the values up to and a few exceeding 100; viz. the work is in five divisions, relating to the cases

I. (pp. 1–171), degree any odd prime of the first 100, viz. 3, 5, 7, 11, 13, 17, 19, 23, 29, 31, 37, 41, 43, 47, 53, 59, 61, 67. 71, 73, 79, 83, 89, 97;

II. (pp. 173–192), degree the power of an odd prime 9, 25, 27, 49, 81;

III. (pp. 193–440), degree a product of two or more odd primes or their powers, viz. 15, 21, 33, 35, 39, 45, 51, 55, 57, 63, 65, 69, 75, 77, 85, 87, 91, 93, 95, 99, 105;

IV. (pp. 441–466), degree an even power of 2, viz. 4, 8, 16, 32, 64, 128;

V. (pp. 467–671), degree divisible by 4, viz. 12, 20, 24, 28, 36, 40, 44, 48, 52, 56, 60, 68, 72, 76, 80, 84, 88, 92, 96, 100, 120;

the only excluded degrees being those which are the double of an odd prime, these, in fact, coming under the case where the degree is the odd prime itself.

It would be somewhat long to explain the specialities which belong to degrees of the forms II., III., IV., V.; and what follows refers only to Division I., degree an odd prime.

For instance, $\lambda=7$, $\lambda-1=2\cdot3$, the factors of 6 are 6, 3, 2, 1; and there are accordingly four divisions,

I. α a prime seventh root or root of $\alpha^6+\alpha^5+\alpha^3+\alpha^2+\alpha+1=0$.

II. $\eta_0=\alpha+\alpha^{-1}, \eta_1=\alpha^2+\alpha^{-2}, \eta_2=\alpha^3+\alpha^{-3}$, or η a root of $\eta^3+\eta^2-2\eta-1=0$ $\left\{\begin{array}{l}\eta_0{}^2=2+\eta_1,\ \eta_1{}^2=2+\eta_2, \text{ \&c.}\\ \eta_0\eta_1=\eta_0+\eta_2, \text{ \&c.}\\ \eta_0\eta_2=\eta_1+\eta_2, \text{ \&c.}\end{array}\right.$

III. $\eta_0=\alpha+\alpha^2+\alpha^4$, $\eta_1=\alpha^3+\alpha^5+\alpha^6$, or η a root of $\eta^2+\eta+2=0$.

IV. Real numbers.

I. $p=7m+1$. (1) gives for the several prime numbers of this form 29, 43 .... 967 the congruence roots, mod. p; for instance,

p	α	α^2	α^3	α^4	α^5	α^6
29	-5	-4	-9	-13	$+7$	-6
43	$+11$	-8	-2	$+21$	$+16$	$+4$
:						

this means $\alpha\equiv-5$ (mod. 29); then $\alpha^2\equiv25, \equiv-4$, $\alpha^3\equiv20, \equiv-9$, &c., values which satisfy the congruence $\alpha^6+\alpha^5+\alpha^4+\alpha^3+\alpha^2+\alpha+1\equiv0$ (mod. 29).

(2) gives under the simple and the primary form the prime factors $f(\alpha)$ of these same numbers 29, 43....967; for instance,

p	$f(\alpha)$ simple.	$f(\alpha)$ primary.
29	$\alpha+\alpha^2-\alpha^3$	$2+3\alpha-\alpha^2+5\alpha^3-2\alpha^4+4\alpha^5$
43	$\alpha^2+2\alpha^6$	$2\alpha-2\alpha^2+4\alpha^4-\alpha^5-5\alpha^6$.

The definition of a primary form is a form for which $f(\alpha)\,f(\alpha^{-1})\equiv f(1)^2$ mod. λ, and $f(\alpha)\equiv f(1)$ mod. $(1-\alpha)^2$. The simple forms are also chosen so as to satisfy this *last* condition; thus $f(\alpha)=\alpha+\alpha^2-\alpha^3$, then $f(1)-f(\alpha)=1-\alpha-\alpha^2+\alpha^3=(1-\alpha)^2(1+\alpha), \equiv0$ mod. $(1-\alpha)^2$.

II. $p=7m-1$. (1) gives for the several prime numbers of this form 13, 41....937 the congruence roots, mod. p; for instance,

p	η_0	η_1	η_2
13	-3	-6	-5
41	-4	$+14$	-11
⋮			

and (2) gives under the simple and the primary forms the prime factors $f(\eta)$ of these same numbers 13, 41....937; for instance,

p	$f(\eta)$ simple.	$f(\eta)$ primary.
13	$\eta_0+2\eta_2$	$3+7\eta_1$
41	$4+\eta_0$	$-11+7\eta_1-7\eta_2$.
⋮		

Thus $13=(\eta_0+2\eta_2)(\eta_1+2\eta_0)(\eta_2+2\eta_1)$, as is easily verified; the product of first and second factors is $=4+3\eta_0+8\eta_1+5\eta_2$, and then multiplying by the third factor result is $42+29(\eta_0+\eta_2)$, $=13$.

III. $p=7m+2$ or $7m+4$. (1) gives for the several prime numbers of this form 2, 11, ... 991 the congruence roots, mod. p; for instance,

p	η_0	η_1
2	0	-1
11	4	-5
⋮		

and (2) gives the primary prime factors $f(\eta)$ of these same numbers:—

p	$f(\eta)$
2	η_0
11	$1-2\eta_1$.

IV. $p=7m+3$ or $7m+5$. The prime numbers of these forms, viz. 3, 5, 17, 19 .... 997, are primes in the complex theory, and are therefore simply enumerated.

The arrangement is the same for the higher prime numbers $\lambda=23$ &c., for which ideal factors make their appearance, but it presents itself under a more complicated form. Thus $\lambda=23$, $\lambda-1=2\,.\,11$, and the factors of 22 are 22, 11, 2, 1. There are thus four sections.

I. α a prime root, or $\alpha^{22}+\alpha^{21}\ldots\ldots+\alpha^2+\alpha+1=0$.
II. $\eta_0=\alpha+\alpha^{-1}$, ... $\eta_{10}=\alpha^{11}+\alpha^{-11}$, or η a root of
$\eta^{11}+\eta^{10}-10\eta^9\ldots\ldots+15\eta^2-6\eta-1$.
III. $\eta_0=\alpha+\alpha^2$, $\eta_1=\alpha^{-1}+\alpha^{-2}$, or η a root of $\eta^2+\eta+6=0$.
IV. Real numbers.

I. $p=23m+1$ gives for the prime numbers of this form 47, 139....967 congruence roots mod. p and *also* congruence roots mod. p^3*; these last in the form $a+bp+cp^2$, where a is given in the former table; thus first table:—

p	α	α^2	$\alpha^3\ldots\ldots$	α^{22}
47	6	-11	-19	$+8$;

and second table—

p	α	α^2	α^3	$\ldots\ldots\alpha^{22}$
47	$+p-2p^2$	$+13p-23p^2$	$+19p-8p^2$	$+22p+22p^2$,

The meaning is that, $p=47$, the roots of the congruence

$$\alpha^{22}+\alpha^{21}+\ldots\ldots+\alpha^2+\alpha+1\equiv0 \text{ (mod. } 47^3)$$

are

$$\alpha=6+p-2p^2,\ \alpha^2=-11+13p-23p^2,\ \text{\&c.}$$

---

* Where, as presently appearing, 3 is the index of ideality or power to which the ideal factors have to be raised in order to become actual.

I. (2) then gives $f(a)$ the actual ideal prime factor of these same primes 47, 139. . . .967; viz. the whole of this portion of the table $\lambda=23$, I. (2) is, having actual prime factors,

p	$f(a)$
599	$a+a^{16}-a^{17}$
691	$a^3+a^{21}+a^{22}$
829	$a^2+a^5+a^{46}$;

having ideal factors, their third powers actual,

p	$f^3(a)$
47	$a^4+a^5+a^9+a^{10}+a^{16}-a^{20}+a^{22}$
139	$1-a^3-a^7+a^9+a^{11}+a^{14}+a^{15}+a^{17}+a^{18}+a^{20}+a^{21}$
277	$a^2-a^4-a^6+a^7-a^{10}-a^{15}-a^{17}+a^{21}+a^{22}$
461	$a-a^2+a^3-a^9+a^{11}-2a^{15}$
967	$a^2-a^3-a^5+a^{10}+a^{15}-2a^{16}+a^{17}+a^{19}$.

I repeat the explanation, that for the number 47 this means $f(a)f(a^2)\ldots\ldots f(a^{22})=47^3$.

And the like further complication presents itself in the part III. of the same table, $\lambda=23$ (not, as it happens, in part II., nor of course in the concluding part IV., which is a mere enumeration of real primes); thus III. (1) we have congruences (mod. p^3),

$$p=2,\ \eta\equiv-2,\ p=3,\ \eta_0=+12,\ \&c.;$$

and having actual prime factors,

p	$f(\eta)$
59	$5-2\eta_1$
101	$1-4\eta_1$;

⋮

and having ideal prime factors, their third powers actual,

p	$f^3(\eta)$
2	$1-\eta_1$
3	$1-2\eta_1$;

⋮

as regards these last the signification being

$$2^3=(1-\eta_0)(1-\eta_1),\ \eta_0+\eta_1=-1,\ \eta_0\eta_1=6 \text{ (as is at once verified),}$$
$$3^8=(1-2\eta_0)(1-2\eta_1);$$

but the simple numbers 2, 3 are neither of them of the form $(a+b\eta_0)(a+b\eta_1)$.

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§ 7. *Tables* F. *Arithmological.*

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Report of the Committee, consisting of W. SPOTTISWOODE, *F.R.S.*, Professor STOKES, *F.R.S.*, Professor CAYLEY, *F.R.S.*, Professor CLIFFORD, *F.R.S., and* J. W. L. GLAISHER, *F.R.S., appointed to report on Mathematical Notation and Printing, with the view of leading Mathematicians to prefer in optional cases such forms as are more easily put into type, and of promoting uniformity of notation.*

WITH a view to the questions referred to them for consideration, your Committee have made inquiries into the nature and processes of mathematical printing, and the difficulties attendant thereon; and it appears to them that a statement of the results of these inquiries will form the best introduction to the suggestions which they have to make.

The process of "composition" of ordinary matter consists in arranging types uniform in height and depth (or "body" as it is termed) in simple straight lines. The complications peculiar to mathematical matter are mainly of two kinds.

First, figures or letters, generally of a smaller size than those to which they are appended, have to be set as indices or suffixes; and consequently, except when the expressions are of such frequent occurrence as to make it worth while to have them cast upon type of the various bodies with which they are used, it becomes necessary to fit these smaller types in their proper positions by special methods. This process, which is called "justification," consists either in filling up the difference between the bodies of the larger and smaller types with suitable pieces of metal, if such exist, or in cutting away a portion of the larger, so as to admit the insertion of the smaller types.

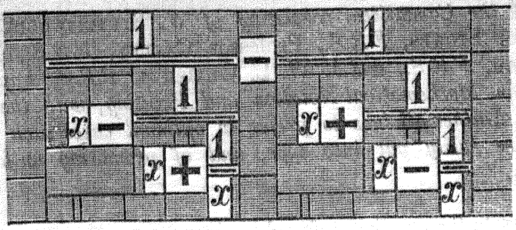
The second difficulty arises from the use of lines or "rules" which occur between the numerator and denominator of fractions, and (in one mode of writing) over expressions contained under radical signs. In whatever part of a line such a rule is used, it is necessary to fill up, or compensate, the thickness of it throughout the entire line. When no letters or mathematical signs occur on a line with the rule the process is comparatively simple; but when, for example, a comma or sign of equality follows a fraction, or a + or − is prefixed to it, the middle of these types must be made to range with the rule itself, and the thickness of the rule must be divided, and half of it placed above and half below the type.

The complications above described may arise in combination, or may be repeated more than once in a single expression; and in proportion as the pieces to be "justified" become smaller and more numerous, so do the difficulties of the workman, the time occupied on the work, and the chances of subsequent dislocation of parts augment.

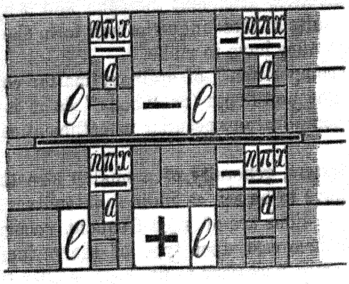
The cost of "composing" mathematical matter may in general be estimated at three times that of ordinary or plain matter.

With a view of illustrating these remarks, we have taken as an example an expression of not unfrequent occurrence in mathematics, but of considerable difficulty to the printer, and have marked out in compartments the different types of which it has to be composed. The shaded parts represent the "justification" spoken of.

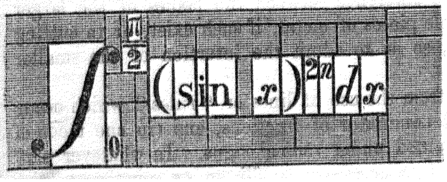
A.



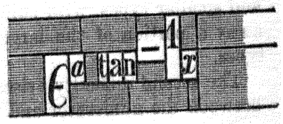
B.



C.



D.



There are many expressions occurring in mathematics which are capable of being written in more than one way; and of these some present much greater difficulties to the printer than others. This being so, your Committee are of opinion that, instead of making any specific recommendations, the most useful course they can take will be to append a table of equivalent forms, specifying those which do and those which do not involve justification, and also a list of mathematical signs which may fairly be expected to be found, in the usual sizes, ready to hand among a printer's materials. It will, of course, be understood that neither one nor other of these is even nearly exhaustive. But the specimens here given form the principal elements from which others are formed; and from the explanations given in the earlier part of the Report the intelligent reader will be able to discriminate in most cases between forms difficult and forms easy to be printed.

In recommending in this qualified way some forms of notation in preference to others, your Committee wish it to be distinctly understood that they are speaking from the printing, and not from the scientific point of view; and they are quite aware that, even if some of the easier forms should be adopted in some cases, they may still not be of universal application, and that there may be passages, memoirs, or even whole treatises in which they would be inadmissible.

Your Committee are unwilling to close this Report without alluding to the advantages which may incidentally accrue to mathematical science by even a partial adoption of the modifications here suggested. Any thing which tends towards uniformity in notation may be said to tend towards a common language in mathematics; and whatever contributes to cheapening the production of mathematical books must ultimately assist in disseminating a knowledge of the science of which they treat.

MATHEMATICAL SIGNS NOT INVOLVING "JUSTIFICATION."

$$\times \quad - \quad + \quad = \quad \surd \quad \pm \quad :\cdot \quad \therefore \quad \because \quad : \quad \} \quad < \quad > \quad \div$$

$$\Big(\quad \Big[\quad \Big\} \quad \int \quad \Big\surd$$

$$a \quad a^1 \quad a_1 \quad a^2 \quad a_2 \quad \text{\&c.,} \quad a^{\frac{1}{2}} \quad a_{\frac{1}{2}}$$

EQUIVALENT FORMS.

Involving justification.	Not involving justification.
$\frac{x}{a}$	$x \div a$ or $x : a$
$\sqrt{x}$	$\surd x$ or $x^{\frac{1}{2}}$
$\sqrt[3]{x}$	$\sqrt[3]{\,}x$ or $x^{\frac{1}{3}}$
$\sqrt{x-y}$	$\surd(x-y)$ or $(x-y)^{\frac{1}{2}}$
$\sqrt{-1}$	i
$x\,.\,\overline{x+a}$	$x(x+a)$
$\epsilon^{\frac{n\pi x}{a}}$	$\exp\,(n\pi x)\,(a)$
$\tan^{-1}x$	arc tan x
$\frac{x}{l}=\frac{y}{m}=\frac{z}{n}$	$x : y : z = l : m : n$

Second Report of the Committee appointed to investigate Intestinal Secretion.

By DR. LAUDER BRUNTON *and* DR. PYE-SMITH.

THE experiments carried out by your Committee last year (*vide* p. 54 of Report for 1874) were directed, first, to ascertain the relative effect of various neutral salts locally applied to the small intestine; secondly, to determine the inhibitory action of drugs injected into the circulation in modifying the above effects; and thirdly, to ascertain the precise manner in which the intestinal secretion is affected by the nervous system. Referring to the Appendices to our last Report for the contributions your Committee were able to make towards the solution of the first two of these problems, our resent investigations have concerned the question of the innervation of the small intestine with regard primarily to its secretion, but also to its nutrition, its blood supply, and its movements. We had already ascertained that the paralytic profuse secretion, after division of the mesenteric nerves, which was first observed by Moreau in dogs and rabbits, also occurs in the case of cats.

It remained to ascertain the centre and the channel of the inhibitory influence which, according to the best-known analogy, that of the submaxillary gland, must be supposed to control, under normal conditions, the intraparietal vasomotor and secretory ganglia of the small intestine.

Before relating our own experiments, we may shortly refer to the results obtained by previous observers.

The first facts we have been able to find which bear on the question were observed as long ago as 1853 by Ludwig and Haffter *, who ascertained that after dividing the great splanchnic nerves there was no important alteration in the intestinal secretion, although a slightly increased degree of moisture of the mucous membrane in the upper part of the small intestine could occasionally be remarked; nor were the peristaltic movements either stopped or accelerated.

In 1856 Samuel published the results of experiments in which he had extirpated the solar plexus in dogs, cats, and rabbits. He observed diarrhœa in some cases; and after death (which usually occurred between 12 and 24 hours) found the upper part of the intestine hyperæmic, with occasional ecchymoses and shedding of epithelium. The lower half was unaffected; the mucous membrane moist throughout.

In the same year Pincus performed similar experiments on dogs, cats, and rabbits. He also found that after as complete destruction as possible of the solar plexus, the mucous membrane of the upper half of the small intestine was excessively hyperæmic, with extravasations of blood and ulcerations. This observer noticed that hyperæmia of the stomach and duodenum followed section of the vagi. On dividing the cord of the sympathetic on the right side in four places below the diaphragm, he found the mucous membrane of the stomach, small intestine, and cæcum very hyperæmic, with slight hæmorrhage and ulceration, and also extravasation of blood among the muscles of the right thigh. The same operation on the left side produced similar, but less marked effects. Lastly, the abdominal gangliated cord was divided on both sides, and the solar plexus excised. Still more extensive hyperæmia, submucous ecchymoses, and hæmorrhage into the intestine, with "disappearance of whole pieces of mucous membrane," were the result. Unlike Samuel, Pincus did not observe any increased secretion whatever from the intestinal mucous membrane.

Budge, in 1860, found that extirpation of the semilunar ganglia in rabbits produced increased fluidity of the fæces in the cæcum and colon. No mention, however, is made of any thing approaching to paralytic secretion in the small intestine.

In the same year Schiff also observed that, after extirpation of the solar plexus in two cats, the fæces appeared somewhat softer and moister than in healthy animals. He also found that application of an induced current to the divided splanchnics was followed by contraction of the vessels of the stomach and intestine, and anæmia of the chylopoietic viscera, including the spleen, which disappeared on removing the stimulus and returned on reapplying it.

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* Haffter, Henle u. Pfeuffer's Zeitsch. n. F. iv. 3. Samuel, Wien. med. Wochenschr. 30. 1856.

Lastly, Adrian, after extirpation (which he admits to have been imperfect) of the solar plexus, found no alteration whatever in the vascularity, secretion, or movements of the intestine.

Last year your Committee satisfied themselves, by numerous experiments detailed in their Report, that division of both right and left splanchnic nerves was unattended by hæmorrhage, hyperæmia, or excessive secretion of the intestine.

Messrs. Lewis and Cunningham, in their valuable report of researches on cholera, have confirmed these results in the case of dogs. The same observers found in three cases that excision of the left semilunar ganglion, in addition to division of the splanchnics, had no positive effect.

We have ourselves excised the right, the left, and both semilunar ganglia, with division of both splanchnics in each instance, in fourteen experiments, and in no case did we find ecchymoses or excessive secretion. The mucous membrane was frequently pale and dry, sometimes moist. In one instance alone, however, as much as 4½ cubic centimetres of pale opalescent fluid were found in a loop of the ileum four inches in length. In another case a loop of the ileum of the same length, 18 inches from the valve, contained 13 c. c. of fluid. The 35 inches between this loop and the pylorus only contained 12 c. c., and the mucous membrane throughout was normal. In this case the right semilunar ganglion had been completely removed, as was verified after death, but the left ganglion and splanchnic were uninjured. The animal was in full process of digestion, and the lacteals and receptaculum chyli were distended. It was killed four hours after the operation.

We have next repeated the experiments of other physiologists, and have, like them, observed that section of both pneumogastric nerves has no effect upon intestinal secretion. Since division of the vagi in the neck of the cat involves section of the cervical sympathetic, it appeared to your Committee that it has been sufficiently demonstrated that the centre regulating the intestinal nerves does not lie in the ganglionic cord either in the neck or the thorax.

We therefore next endeavoured to ascertain the effect of destruction of the grey matter of the spinal cord, and with this object destroyed the cord from the sixth dorsal vertebra downwards, not only by means of a bougie passed down the vertebral canal, but also by complete removal of the laminæ of the vertebræ and excision of the cord entire. In numerous trials we found that this lesion had no effect upon the vascularity or secretion of the intestine; and even when the vagi were also divided and artificial respiration maintained, the result was negative.

Looking, therefore, to the complete character of the experiments which have been now carried out on the vagus, the splanchnics, and the spinal cord, it would appear to follow, by way of exclusion, that the regulating influence conveyed by the nerves divided in Moreau's experiments must arise from some of the ganglia of the great solar plexus.

That the excision of the semilunar ganglia, in our own hands as in those of other experimenters, has been often followed by a negative result is true; but in three cases we obtained good evidence of a consequent paralytic secretion; and the difficulty of this operation, as well as the varying number and irregular arrangement of the ganglia of the solar plexus in the cat, may not improbably explain the more numerous failures.

It might be supposed, however, that the non-appearance of a paralytic secretion from the intestine after destruction, apparently tolerably complete, of the solar plexus, while it occurs after division of the mesenteric nerves going to a single loop of intestine, might be due to the blood going to any one part being insufficient to supply the material for secretion; for, in Morceau's experiment, the nerves going to a part of the intestine only are divided, and any relaxation of the vessels of that part which succeeds the operation will increase the supply of blood to the intestinal loop operated upon, as the vessels in the after parts still retain their normal tone, and the blood naturally flows in the direction of least resistance. When, however, the splanchnics, which are the chief vasomotor nerves of the intestine, are cut and the solar plexus destroyed, the vessels of the whole intestine become dilated and the flow of blood through every part languid.

Such an explanation appears all the more probable from the fact observed by Cyon and Aladoff that section of the vasomotor nerves of the liver alone increased the flow of blood through the organ and produced diabetes, while section of these same fibres was not followed by this result if the intestinal vasomotor nerves contained with them in the splanchnics were divided at the same time. The reason assigned is that in the former case the blood flowed easily through the dilated vessels of the liver, and a proportionately small quantity through those of the intestine; while in the latter, the vessels being all dilated, there was not sufficient pressure to keep up an active circulation anywhere. In order, then, to avoid this source of fallacy, your Committee repeated their experiments on the section of the splanchnics and excision of the solar plexus, but at the same time ligatured the aorta between the mesenteric and renal arteries, so that the pressure in the vessels of the intestines might be maintained as nearly as possible normal. These experiments also yielded a negative result, so that the failure of the previous series cannot have been due to diminished supply of blood to the intestine.

Apart from paralytic secretion, a striking result thrice obtained by your Committee was the occurrence of extravasations of blood into the mucous membrane of a great part of the small intestine, and the exudation of a bloody fluid into its lumen, after simultaneous destruction of the solar plexus and of the lower part of the spinal cord (Nos. 18, 19, 20). Although Samuel and Pincus had noticed this after destruction of the solar plexus alone, your Committee only observed it once, under these conditions, in the case of the dog (No. 23); while ecchymoses and extravasations were absent in all other cases, even when they succeeded in obtaining a paralytic secretion of fluid. Nor did your Committee observe hæmorrhage in any case after destruction of the spinal cord and division of the splanchnics alone, even when this was accompanied by section of the vagi.

In three out of the six experiments, on the other hand, in which the solar plexus and spinal cord were simultaneously destroyed, extravasations occurred to a most remarkable extent (Nos. 18, 19, 20). In one at least of the others their absence might be accounted for by the weak condition of the circulation. Another result, worthy of special notice, is the occurrence of vomiting in one animal after division of the vagus and splanchnic nerves on both sides.

While the problem which has baffled so many previous investigations cannot yet be considered as solved, your Committee hope that their experiments may be considered to have proved the absence of influence on the intestinal secretion through the splanchnic nerves, the pneumogastrics, the sympathetic above the diaphragm, or the spinal marrow, and the probable influence of the ganglia contained in the solar plexus, though certainly not of the two semilunar ganglia exclusively. Also the independent occurrence of hæmorrhage and of paralytic secretion appear to point to a separate nervous influence on the blood-vessels and the secreting structures of the intestine.

APPENDIX.

No. of Experiment.	Anæsthetic employed.	Lesion.	Hours.	Result.
1.	Chloroform..	Cord divided between D vi and vii.	25 . . .	Small intestine empty. Mucous membrane pale and dry.
2.	Ditto	Cord divided as in 1, and destroyed by a wire down to L ii.	24	Intestine empty. Mucous membrane pale and moist in duodenum, which contained worms: elsewhere dry.
3.	Ditto	Laminæ removed from D vii to L iii, and cord removed. Part below destroyed by a wire.	23 . .	Intestine empty. Mucous membrane dry, less anæmic. Duodenum contained worms.
4.	Ditto . ..	Laminæ removed from D vii–x and cord removed. Part below destroyed by a hot wire.	Died within about 2 hours.	Intestine empty and anæmic. Mucous membrane dry.
5.	Ditto	Both splanchnics cut. Cord divided at D vii or viii. Part below destroyed by a catgut bougie.	4 . .	Intestine empty, not anæmic. Mucous membrane dry. Peristalsis active.
6.	Ditto	Both splanchnics cut. Both vagi cut. Tracheotomy.	3....	Intestine empty. Mucous membrane dry. Peristalsis active. This cat vomited bilious fluid several times shortly before being killed.
7.	Ditto	Both splanchnics cut. Both vagi cut. Tracheotomy. Cord divided between D vi and vii, and destroyed below that point by a bougie.	3. .	Intestine empty. Hyperæmia of mucous membrane and peritoneum.
8.	Ditto	Both splanchnics cut. Aorta ligatured between sup. mesenteric and renal arteries. Cord divided and destroyed as in 7.	Died almost directly	Intestine empty, tightly contracted. Mucous membrane dry.
9.	Ditto	Both splanchnics cut. Both vagi cut. Tracheotomy. Aorta ligatured between sup. mesenteric and renal arteries. Cord divided and destroyed as in 7.	1... .. .	Intestine emptied and contracted. Mucous membrane moist, with a little bile-stained fluid in lower part of ileum.

Appendix (*continued*).

No. of Experiment.	Anæsthetic employed.	Lesion.	Hours.	Result.
10.	Chloroform.	Right splanchnic cut (artificial respiration).	Died immediately.	Lungs emphysematous, with patches of lobular grey hepatization.
11.	Ditto	Both splanchnics cut. Both vagi cut. Tracheotomy. Cord destroyed as in 7.	3	Hyperæmia of parietal and visceral peritoneum. Intestine empty. Mucous membrane injected, but dry.
12.	Ditto	Both splanchnics cut. Aorta ligatured above renal arteries.	2¼	Intestine contained a little fluid. Mucous membrane hyperæmic.
13.	Ditto	Right splanchnic cut, left incompletely. Right and left vagi cut. Cord destroyed as in 7.	4	Intestine contained a small quantity of bile-stained fluid and some worms. Mucous membrane anæmic.
14.	Ditto	Both splanchnics cut. Both vagi cut. Aorta ligatured above renal arteries. Cord destroyed as in 7.	Died immediately.	General hyperæmia. Upper part of intestine empty, lower contained yellow liquid fæces.
15.	Chloroform. Chloral, gr. xxx.	Three loops ligatured. Nerves to middle one cut. All its vessels but one artery and one vein ligatured.	4¼	Upper loop empty; mucous membrane dry. Lower loop empty; mucous membrane moist. Middle loop empty: two fluid drams of a brownish liquid.
16.	Chloral, gr. xxx.	Same operation as 15.	Died quickly after.	All the loops empty. Mucous membrane pale.
17.	Chloroform.	Both semilunar ganglia completely removed Cord destroyed as in 7. 4 inches of upper jejunum and 4 of lower ileum ligatured off.	3½	Intestine full. Above 1st loop (5 in.) 9 c.c. of bile-stained fluid. In 1st loop (6 in.) 1 c. c. turbid fluid. Between loops (31 in.) 22 or 23 c. c. turbid fluid. In lower loop (14 in.) 17½ c.c. turbid brown fluid. No worms. Mucous membrane generally pale.
18.	Chloroform.	Both semilunar ganglia removed. Cord destroyed as in 7. Loop (5½ inches) a foot below pylorus. Second (3½ inches) 3 inches above valve.	4½........	First loop (nearly 2 ft. below pylorus) empty and contracted. Mucous membrane normal. Second looked full, but only contained a small quan-

Appendix (*continued*).

No. of Experiment.	Anæsthetic employed.	Lesion.	Hours.	Result.
		(Both loops squeezed empty.)		tity of moist fæces. Between the loops intestines contained 30 c. c. of blood-stained fluid. Mucous membrane ecchymosed.
19.	Ether & Chloroform.	Cord destroyed as in 7. Cotton-wool soaked in Tr. Ferri. perchl. thrust down canal. Unusually abundant fluid in peritoneum. Both semilunar ganglia removed.	About 5.	Intestine empty. Mucous membrane pale, with patches of ecchymosis.
20.	Ether.	Cord destroyed, as in 7. Unusually abundant fluid in peritoneum. Both semilunar ganglia removed.	About 4.	Intestine contained very little fluid. Mucous membrane ecchymosed*.
21.	Ether.	Both splanchnics divided, and semilunar ganglia excised†(only an ordinary amount of fluid in the peritoneum). Cord divided and destroyed as in 7.	Died about 3 hours after operation.	Small intestine contained 27 c. c. of thin mucus. Mucous membrane very anæmic throughout.
22.	Chloroform.	Cord exposed from D vi to Cauda Equina, and removed. Small intestine ligatured at cæcum, 6 in. above, and 12 in. above that. Both ganglia excised.	1 hour.	From pylorus to first ligature (12 in.) contained a little bile-stained thin mucus. Mucous membrane pale. Between the two ligatures (16 in.) the same: in neither enough to measure. From second ligature to cæcum appeared full; but on opening it there was only a little mucus and liquid fæces. Mucous membrane pale and moist.
23.‡	Chloroform.	Right and left splanchnics divided, and the largest nerve divided in the root of the mesentery.	3........	From 2 inches below pylorus down to ileo-cæcal valve mucous membrane intensely congested with hæmorrhage: covered with tenacious mucus.

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* Epithelium not granular. Surface shed more or less completely. Deeper layer perfect. Vessels of villi crowded with blood-corpuscles.

† About this time a great mortality occurred in cats under ether. Previously several had died from catarrh while under chloroform.

‡ In this experiment a dog was used: all those preceding were on cats.

Third Report of the Sub-Wealden Exploration Committee, consisting of HENRY WILLETT, *F.G.S.*, R. A. C. GODWIN-AUSTEN, *F.R.S.*, W. TOPLEY, *F.G.S.*, T. DAVIDSON, *F.R.S.*, Prof. J. PRESTWICH, *F.R.S.*, Prof. BOYD DAWKINS, *F.R.S.*, *and* HENRY WOODWARD, *F.R.S. Drawn up by* HENRY WILLETT, *F.G.S.*

OF the £150 granted by the Committee of Recommendations in furtherance of this undertaking, £25 was voted in 1872, and, as reported at Bradford, in the subsequent twelve months, 295 feet of strata were penetrated at a diameter of 9 inches.

The second grant of £25, made in 1873, encouraged an enlarged subscription of sufficient amount to warrant the Committee in entering into a contract with the Diamond Boring Company to extend, by their process (at a diameter of 3 inches), the bore-hole to 1000 feet. This depth was successfully reached on the 18th of June, 1874.

In the report made at Belfast it was announced that the Government had (in consequence of a memorial signed on behalf of their Councils, by the Presidents of the Royal Society, of the Geological Society of London, and of the Society of Engineers) consented to a Treasury grant of £1000, to be paid on the condition that beyond the depth of 1000 feet an additional 1 foot should be explored for every £1 of the aforesaid grant.

The foregoing facts induced the Committee of Recommendations at Belfast to give further assistance by a third and enlarged grant of £100. Thus again encouraged, the Committee arranged a contract with the Diamond Boring Company for an extension to 1200 feet, at an additional cost of £400; but at 1018 feet the strata were found to be so much broken and fissured that it became absolutely essential to line the entire depth. The estimated cost of this operation was an additional £400.

Engineering difficulties of an unforeseen and of a finally insurmountable nature ensued; and, in consequence, the Treasurer of the British Association was informed, in October 1874, that the grant might possibly not be required—at any rate, not at that time.

In January 1875 the contractors, with laudable courage and energy, volunteered to commence *de novo*, and to put down a bore-hole of considerably enlarged diameter, which should be lined at their expense to the depth of 1000 feet, at a cost, including lining tubes, of £600; viz. of £200 only beyond what had been agreed upon as the price for lining the old 3-inch diameter.

This work, begun on February 12th, 1875, went on uninterruptedly, as will be seen by the subjoined statement:—

								Diameter of core.
Bored at	8 in.	diam.,	28 ft.	Lined with	8-in.	tube,	28 ft.	6 in.
„	7 in.	„	49 ft.	„	7-in.	„	77 ft.	6 in.
„	6 in.	„	168 ft.	„	6-in.	„	245 ft.	5 in.
„	5 in.	„	594 ft.	„	5-in.	„	839 ft.	4 in.
„	4 in.	„	295 ft.	„	4-in.	„	1134 ft.	3 in.
„	3 in.	„	536 ft.	„	3-in.	„	1670 ft.	2¼ in.
„	2⅛ in.	„	92 ft.				1762 ft.	1 in.
			1762 ft.					

It should be remembered that the problem originally offered for solution was one based on the strong opinion expressed by our most eminent geologists, that there was a high degree of probability that Palæozoic rocks (following the course of the axis of Artois, and dipping beneath the surface in Belgium and the north of France) would be found at a depth variously estimated at from 700 feet to 1700 feet.

In this aspect the problem is solved, a depth of 1753 feet having been explored with the certainty that (within the aforesaid maximum distance) no such rocks exist in this locality.

On the contrary, an extraordinary and unexampled thickness of sedimentary beds, possessing many features of the Jurassic series, with a fauna most persistent in type, and such as has hitherto been considered to denote the Kimmeridge Clay of England and of the Continent, is the result so far of the discoveries made by the Sub-Wealden Exploration.

Although no economic advantages were ever sought by the promoters, two not unimportant results have ensued:—

1. A company has been established for developing the rich beds of gypsum which we have discovered, and which were hitherto unknown to exist in Sussex.

2. We have proved that the project for supplying Hastings with water by means of a deep well on the Artesian system would be abortive.

After three years of toil and anxiety, it is some satisfaction to be able to state further that, owing to the munificent response made by lovers of science, of all orders and degrees of men among us, a contract has been entered into for completion to 2000 feet, should no unavoidable hindrance occur.

No additional grant is solicited, or will be required, from the British Association.

The geological results will be fully explained in more minute detail by Mr. Topley's report, hereunto appended.

To him, to Robert Etheridge, Esq., F.R.S. (for his invaluable palæontological services), to J. H. Peyton, Esq., F.G.S. (for numberless journeys of inspection to the works), to Prof. Ramsay, to the Committee of Scientific Reference, over which he has so ably presided, and to the Patrons and Subscribers who have so generously supplied the funds for prosecuting the work, the thanks of all sympathisers with scientific advancement are due.

Although, by Mr. Warner's offer of £300, on reaching 2000 feet, that depth has been named as the maximum limit to be aimed at, yet the friability of the strata at the present depth (1762 feet), and the persistent character of the sedimentary deposits, seem to show the wisdom of stopping any further outlay on the "Sub-Wealden Exploration."

Geological Report by W. Topley, F.G.S., Assoc. Inst. C.E., Geological Survey of England.

In the Report submitted to the Association at Belfast an account was given of the strata passed through and of the fossils found down to a depth of 1013 feet. It was then believed that certain Ammonites found in the lower cores were Oxford-Clay forms; and it was therefore supposed that the boring had passed from the Kimmeridge Clay to the Oxford Clay without finding any representative of the Coral Rag or Calcareous Grit.

The first boring was abandoned at the depth then attained (1013 feet), and a second boring was commenced, which has now (August 1875) reached the depth of 1820 feet. This has proved that the Kimmeridge-Clay fauna extends much lower than was inferred from the results of the first boring. *Gryphæa* (*Exogyra*) *virgula* has been met with at various depths down to 1656 feet. *Ammonites mutabilis* extends from about 960 feet to 1652 feet. *Rhynchonella pinguis* is common in some of the lower cores. The presence of these fossils would seem to settle the question as to the age of the beds in which they occur; but fortunately we are not now left to palæontological evidence alone. At about 1769 feet an oolitic rock was reached, which continued to 1786 feet, where the beds again changed to shale. The upper part of this 17 feet of rock is rather coarse in grain; the lower part is finer. Save as regards colour (which depends on weathering) these cores may be matched precisely by examples of Coralline Oolite in the Museum of the Geological Survey at Jermyn Street. Mr. Bristow kindly referred me to the specimens which are contained in Wall-case No. 46. No. 58 in this case is a rather coarse-grained oolite from Steeple Ashton in Wiltshire, exactly resembling the cores found at about 1770 feet. No. 59 is an oolite of finer grain from Buckland, near Faringdon, which as closely resembles the cores found at about 1782 feet. These rocks are not very fossiliferous; and in the boring they appear to contain only small oysters, which occur chiefly in the lower part. The coarse oolite in the boring is hard, and takes a fine polish; the finer variety is softer.

We may, then, with some degree of safety, assume that these rocks represent the Coral Rag (Coralline Oolite). The Upper and Lower Calcareous Grits are either absent, or they are represented by sandy, rather calcareous shales, which do not in any way differ from shales which are abundant in the true Kimmeridge Clay.

It will perhaps be better to leave the description of the fossils until the materials have been more carefully worked up and the whole series fully arranged; it will also be as well to defer till then a detailed section of the strata. Mr. Etheridge has carefully looked over the cores; and from his notes the foregoing remarks on the fossils are taken.

Mr. H. Woodward has examined the Crustacea, and he refers some remarkably fine examples, found in the Kimmeridge Clay at 1057 feet, to a new species of *Callianassa*. He proposes to call this *C. isochela*; it is the oldest known form of the genus. Fragments of another crustacean were found at the same depth; Mr. Woodward refers this to *Mecochirus Peytoni*, Woodw.

Beds of sandstone have been met with at various depths in the Kimmeridge Clay. Frequently they are traversed by wavy concretionary lines, which look exactly like fossils on the outside of the core. All these sandstones are cemented by carbonate of lime. Oysters are almost the only fossils which they contain. Throughout both borings it has been noticed that oysters are most abundant in the sandy beds.

The shales are frequently traversed by oblique veins of carbonate of lime. The hole, when not lined, is very apt to fall in at these points. In the method of boring employed by the Diamond Company it is necessary to send a stream of water down the middle of the rods from the surface, the water rising again to the surface outside the rods. Mr. Thornton, the engineer in charge, noticed that the hole fell in much more readily after heavy rain, when the brook from which the water was pumped was swollen, than it did when the brook only ran with spring-water. He referred this, no doubt correctly, to the superior solvent power for carbonate of lime of the rain-water charged with carbonic acid.

The Kimmeridge Clay probably began at about 274 or 275 feet from the surface. If it extends to 1769 feet, we have here a thickness of 1495 feet in one continuous section, all the beds lying flat. The greatest thickness assumed by Mr. Blake for the Kimmeridge Clay of England, where exposed at the surface, is 1050 feet; this thickness, however, is not present in any one district.

The Report of the Committee appointed for the purpose of considering the use of Steel for structural purposes will be printed in the next volume.

NOTICES AND ABSTRACTS

OF

MISCELLANEOUS COMMUNICATIONS TO THE SECTIONS.

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MATHEMATICS AND PHYSICS.

Address by Professor Balfour Stewart, *M.A., LL.D., F.R.S., President of the Section.*

Since the last meeting of the British Association science has had to mourn the loss of one of its pioneers in the death of the veteran astronomer Schwabe, of Dessau, at a good old age, not before he had faithfully and honourably finished his work. In truth this work was of such a nature that the worker could not be expected long to survive its completion.

It is now nearly fifty years since he first began to produce daily sketches of the spots that appeared upon the sun's surface. Every day on which the sun was visible (and such days are more frequent in Germany than in this country), with hardly any intermisssion for forty years, this laborious and venerable observer made his sketch of the solar disk. At length this unexampled perseverance met with its reward in the discovery of the periodicity of sun-spots, a phenomenon which very speedily attracted the attention of the scientific world.

It is not easy to overrate the importance of the step gained when a periodicity was found to rule these solar outbreaks.

A priori, we should not have expected such a phenomenon.

If the old astronomers were perplexed by the discovery of sun-spots, their successors must have been equally perplexed when they ascertained their periodicity.

For while all are ready to acknowledge periodicity as one of the natural conditions of terrestrial phenomena, yet every one is inclined to ask what there can be to cause it in the behaviour of the sun himself.

Manifestly it can only have two possible causes. It must either be the outcome of some strangely hidden periodical cause residing in the sun himself, or must be produced by external bodies, such as planets, acting somehow in their varied positions on the atmosphere of the sun.

But whether the cause be an internal or external one, in either case we are completely ignorant of its nature.

We can easily enough imagine a cause operating from the sun himself and his relations with a surrounding medium to produce great disturbances on his surface, but we cannot easily imagine why disturbances so caused should have a periodicity. On the other hand we can easily enough attach periodicity to any effect caused by the planets, but we cannot well see why bodies comparatively so insignificant should contribute to such very violent outbreaks as we now know sun-spots to be.

If we look within we are at a loss to account for the periodicity of solar disturbances, and if we look without we are equally at a loss to account for their magnitude.

But since that within the sun is hidden from our view, it cannot surely be considered blameworthy if astronomers have directed their attention to that without, and have endeavoured to connect the behaviour of sun-spots with the positions of the various planets.

Stimulated, no doubt, by the success which had attended the labours of Schwabe, an English astronomer was the next to enter the field of solar research.

The aim of Mr. Carrington was, however, rather to obtain very accurate records of the positions, the sizes, and the shapes of the various sun-spots, than to make a very extensive and long-continued series of observations. He was aware that a series at once very accurate and very extended is beyond the power of a private individual, and can only be undertaken by an established institution. Nevertheless each sun-spot that made its appearance during the seven years extending from the beginning of 1854 to the end of 1860 was sketched by Mr. Carrington with the greatest possible accuracy, and had also its heliographic positions—that is to say, its solar latitude and longitude—accurately determined

One of the most prominent results of Mr Carrington's labours was the discovery of the fact that sun-spots appear to have a proper motion of their own, those nearer the solar equator moving faster than those more remote Another was the discovery of changes apparently periodical affecting the disposition of spots in solar latitude. It was already known that sun-spots confined themselves to the sun's equatorial regions, but Mr Carrington showed that the region affected was liable to periodical elongations and contractions, although his observations were not sufficiently extended to determine the exact length of this period

Before Mr Carrington had completed his seven years' labours, celestial photography had been introduced by Mr Warren De La Rue Commencing with his private observatory, he next persuaded the Kew Committee of the British Association to allow the systematic photography of the sun to be carried on at their observatory under his superintendence, and in the year 1862 the first of a ten years' series of solar photographs was begun.

Before this date, however, Mr. De La Rue had ascertained, by means of his photoheliograph, on the occasion of the total eclipse of 1860, that the red prominences surrounding the eclipsed sun belong, without doubt, to our luminary himself.

The Kew observations are not yet finally reduced, but already several important conclusions have been obtained from them by Mr. De La Rue and the other Kew observers. In the first place the Kew photographs confirm the theory of Wilson that sun-spots are phenomena the dark portions of which exist at a level considerably beneath the general surface of the sun—in other words, they are hollows or pits, the interior of which is of course filled up with the solar atmosphere. The Kew observers were likewise led to associate the low temperature of the bottom of sun-spots with the downward carriage of colder matter from the atmosphere of the sun, while the upward rush of heated matter was supposed to account for the faculæ or bright patches which almost invariably accompany spots. In the next place, the Kew observers, making use not only of the Kew series but of those of Schwabe and Carrington, which were generously placed at their disposal, have discovered traces of the influence of the nearer planets upon the behaviour of sun-spots. This influence appears to be of such a nature that spots attain their maximum size when carried by rotation into positions as far as possible remote from the influencing planet—that is to say, into positions where the body of the sun is between them and the planet. There is also evidence of an excess of solar action when two influential planets come near together. But although considerable light has thus been thrown on the periodicity of sun-spots, it ought to be borne in mind that the cause of the remarkable period of eleven years and a quarter, originally discovered by Schwabe, has not yet been properly explained. The Kew observers have likewise discovered traces of a peculiar oscillation of spots between the two hemispheres of the sun; and finally their researches will place at the command of the observers the data for ascertaining whether centres of greater and lesser solar activity are connected with certain heliocentric positions.

While the sun's surface was thus being examined both telescopically and photographically, the spectroscope came to be employed as an instrument of research. It had already been surmised by Professor Stokes that the vapour of sodium at a comparatively low temperature forms one of the constituents of the solar atmosphere, inasmuch as the dark line D in the spectrum of the sun coincides in position with the bright line given out by incandescent sodium vapour.

This method of research was greatly extended by Kirchhoff, who soon found that many of the dark lines in the solar spectrum were coincident with the bright lines of sundry incandescent metallic vapours; and a good beginning was thus made towards ascertaining the chemical constitution of the sun.

The new method soon brought forth further fruit when applied, in the hands of Huggins, Miller, Secchi, and others, to the more distant heavenly bodies. It was speedily found that the fixed stars had constitutions very similar to that of the sun. But a peculiar and unexpected success was attained when some of the nebulæ were examined spectroscopically. To-day it seems (so rapidly has knowledge progressed) very much like recalling an old superstition to remind you that, until the advent of the spectroscope, the irresolvable nebulæ were considered to be gigantic and remote clusters of stars, the individual members of which were too distant to be separated from each other even with a telescope like that of Lord Rosse.

But Mr. Huggins, by means of the spectroscope, soon found that this was not the case, and that most of the nebulæ which had defied the telescope gave indications of incandescent hydrogen gas.

It was also found by this observer that the proper motions of some of the fixed stars in a direction to or from the earth might be detected by means of the displacement of their spectral lines, a principle of research which was first enunciated by Fizeau.

Hitherto in such applications of the spectroscope, the body to be examined was viewed as a whole.

It had not yet been attempted to localize the use of this instrument so as to examine particular districts of the sun—as, for instance, a sun-spot, or the red flames already proved by De La Rue to belong to our luminary.

This application was first made by Mr. Lockyer, who, in the year 1865, examined a sun-spot spectroscopically, and remarked the greater thickness of the lines in the spectrum of the darker portion of the spot.

Dr. Frankland had previously found that thick spectral lines correspond to great pressure, and hence the inference from the greater thickness of lines in the umbra of a spot is, that this umbra or dark portion is subject to a greater pressure—that is to say, it exists below a greater depth of the solar atmosphere than the general surface of the sun. Thus the results derived from the Kew photoheliograph and those derived from the spectroscope were found to confirm each other. Mr. Lockyer next caused a powerful instrument to be constructed for the purpose of viewing spectroscopically the red flames round the sun's border, in the hope that if they consisted of ignited gas the spectroscope would disperse, and thus dilute and destroy, the glare which prevents them from being seen on ordinary occasions.

Before this instrument was quite ready, these flames had been analyzed spectroscopically by Capt. Herschel, M. Janssen, and others on the occasion of a total eclipse occurring in India, and they were found to consist of incandescent gas, most probably hydrogen. But the latter of these observers (M. Janssen) made the important observation that the bright lines in the spectrum of these flames remained visible even after the sun had reappeared, from which he argued that a solar eclipse is not necessary for the examination of this region.

Before information of the discovery made by M. Janssen had reached this country, the instrument of Mr. Lockyer had been completed, and he also found that by its means he was able to analyze at leisure the composition of the red flames without the necessity of a total eclipse. An atmosphere of incandescent hydrogen was found to surround our luminary, into which, during the greater solar storms, sundry metallic vapours were injected—sodium, magnesium, and iron forming the three that most frequently made their appearance.

Here we come to an interesting chemical question.

It had been remarked by Maxwell and by Pierce, as the result of the molecular theory of gases, that the final distribution of any number of kinds of gas in a vertical direction under gravity is such that the density of each gas at a given height is the same as if all the other gases had been removed, leaving it alone.

In our own atmosphere the continual disturbances prevent this arrangement from taking place; but in the sun's enormously extended atmosphere (if, indeed, our luminary be not nearly all gaseous) it appears to hold, inasmuch as the upper portion of this atmosphere, dealing with known elements, apparently consists entirely of hydrogen.

Various other vapours are, however, as we have seen, injected from below the photosphere into the solar atmosphere on the occasion of great disturbances; and Mr. Lockyer has asked the question, whether we have not here a true indication of the relative densities of these various vapours derived from the relative heights to which they are injected on such occasions.

This question has been asked, but it has not yet received a definite solution; for chemists tell us that the vapour-densities of some of the gases injected into the sun's atmosphere on the occasion of disturbances are, as far as they know from terrestrial observations, different from those which would be indicated by taking the relative heights attained in the atmosphere of the sun. Mr. Lockyer has attempted to bring the question a step nearer to its solution by showing that the vapours at the temperature at which their vapour-densities have been experimentally determined are not of similar molecular constitution; whereas in the sun we get an indication, from the fact that all the elements give us line spectra, that they are in similar molecular states.

Without, however, attempting to settle this question, I may remark that we have here an interesting example of how two branches of science, physics and chemistry, meet together in solar research.

It had already been observed by Kirchhoff that sometimes one or more of the spectral lines of an elementary vapour appeared to be reversed in the solar spectrum, while the other lines did not experience reversal. Mr. Lockyer succeeded in obtaining an explanation of this phenomenon. This explanation was found by means of the method of localization already mentioned.

Hitherto, when taking the spectrum of the electric spark between the two metallic poles of a coil, the arrangements were such as to give an average spectrum of the metal of these poles; but it was found that when the method of localization was employed, different portions of the spark gave a different number of lines, the regions near the terminals being rich in lines, while the midway regions give comparatively few.

If we imagine that in the midway regions the metallic vapour given off by the spark is in a rarer state than that near the poles, we are thus led to regard the short lines which cling to the poles as those which require a greater density or nearness of the vapour particles before they make their appearance; while, on the other hand, those which extend all the way between the two poles come to be regarded as those which will continue to make their appearance in vapour of great tenuity.

Now it was remarked that these long lines were the very lines which were reversed in the atmosphere of the sun. Hence when we observe a single coincidence between a dark solar line and the bright line of any metal, we are further led to inquire whether this bright line is one of the long lines which will continue to exist all the way between two terminals of that metal when the spark passes.

If this be the case, then we may argue with much probability that the metal in question really occurs in the solar atmosphere; but if, on the other hand, the coincidence is merely between a solar dark line and a short bright one, then we are led to imagine that it is not a true coincidence, but something which will probably disappear on further examination. This method has already afforded us a means of determining the relative amount of the various metallic vapours in the sun's atmosphere. Thus, in some instances all lines are reversed, whereas in others the reversal extends only to a few of the longer lines.

Several new metals have thus been added to the list of those previously detected in the solar atmosphere; and it is now certain that the vapours of hydrogen, potassium, sodium, rubidium, barium, strontium, calcium, magnesium, aluminium, iron, manganese, chromium, cobalt, nickel, titanium, lead, copper, cadmium, zinc, uranium, cerium, vanadium, and palladium occur in our luminary.

I have spoken hitherto only of telescopic spectroscopy; but photography has been found capable of performing the same good service towards the compound instrument consisting of the telescope and its attached spectroscope, which it had previously been known to perform towards the telescope alone.

It is of no less importance to secure a permanent record of spectral peculiarities than it is to secure a permanent record of telescopic appearances.

This application of photography to spectrum observations was first commenced on a sufficient scale by Mr. Rutherford, of New York, and already promises to be one of the most valuable aids in solar inquiry.

In connexion with the spectroscope I ought here to mention the names of Respighi and Secchi, who have done much in the examination of the solar surface from day to day. It is of great importance to the advancement of our knowledge, that two such competent observers are stationed in a country where the climate is so favourable to continued observation.

The examination of the sun's surface by the spectroscope suggests many interesting questions connected with other branches of science. One of these has already been alluded to.

I may mention two others put by Mr. Lockyer, premising, however, that at present we are hardly in a position to reply to them.

It has been asked whether the very high temperatures of the sun and of some of the stars may not be sufficient to produce the disassociation of those molecular structures which cannot be disassociated by any terrestrial means; in other words, the question has been raised, whether our so-called elements are really elementary bodies.

A third question is of geological interest. It has been asked whether a study of the solar atmosphere may not throw some light upon the peculiar constitution of the upper strata of the earth's surface, which are known to be of less density than the average interior of our planet.

If we have learned to be independent of total eclipses as far as the lower portions of the solar atmosphere are concerned, it must be confessed that as yet the upper portions—the outworks of the sun—can only be successfully approached on these rare and precious occasions. Thanks to the various Government expeditions despatched by Great Britain, by the United States, and by several Continental nations—thanks, also, to the exertions of Lord Lindsay and other astronomers—we are in the possession of definite information regarding the solar corona.

In the first place, we are now absolutely certain that a large part of this appendage unmistakably belongs to our luminary; and in the next place, we know that it consists, in part at least, of an ignited gas giving a peculiar spectrum, which we have not yet been able to identify with that of any known element.

The temptation is great to associate this spectrum with the presence of something lighter than hydrogen, of the nature of which we are yet totally ignorant.

A peculiar physical structure of the corona has likewise been suspected. On the whole, we may say that this is the least known, while it is perhaps the most interesting, region of solar research; most assuredly it is well worthy of further investigation.

If we now turn our attention to matters nearer home, we find that there is a difficulty in grasping the facts of terrestrial meteorology no less formidable than that which assails us when we investigate solar outbreaks. The latter perplex us because the sun is so far away, and because also his conditions are so different from those with which we are here familiar; while, on the other hand, the former perplex us because we are so intimately mixed up with them in our daily lives and actions—because, in fact, the scale is so large and we are so near. The result has been that until quite recently our meteorological operations have been conducted by a band of isolated volunteers, individually capable and skilful, but from their very isolation incapable of combining together with advantage to prosecute a scientific campaign. Of late, however, we have begun to perceive that if we are to make any advance in this very interesting and practical subject, a different method must be pursued, and we have already reaped the first fruits of a more enlightened policy; already we have gained some knowledge of the constitution and habits of our atmosphere.

The researches of Wells and Tyndall have thrown much light on the cause of dew. Humboldt, Dove, Buys Ballot, Jelinek, Quetelet, Hansteen, Kupffer, Forbes, Welsh, Glaisher, and others have done much to give us an accurate knowledge of the distribution of terrestrial temperature.

Great attention has likewise been given to the rainfall of Great Britain and Ireland, chiefly through the exertions of one individual, Mr. G. J. Symons.

To Dove we are indebted for the law of rotation of the wind, to Redfield for the spiral theory of cyclones, to Francis Galton for the theory of anti-cyclones, to Buchan for an investigation into the disposition of atmospheric pressure which precedes peculiar types of weather, to Stevenson for the conception of barometric gradients, to Scott and Meldrum for an acquaintance with the disposition of winds which frequently precedes violent outbreaks; and, to come to the practical application of laws, we are much indebted to the late Admiral FitzRoy and the system which he greatly helped to establish for our telegraphic warnings of coming storms.

Again, the meteorology of the ocean has not been forgotten. The well-known name of Maury will occur to every one as that of a pioneer in this branch of inquiry. FitzRoy, Leverrier, Meldrum, Toynbee, and others have likewise done much; and it is understood that the meteorological offices of this and other maritime countries are now busily engaged upon this important and practical subject. Finally, the movements of the ocean and the temperatures of the oceanic depths have recently been examined with very great success in vessels despatched by Her Majesty's Government; and Dr. Carpenter has by this means been able to throw great light upon the convection-currents exhibited by that vast body of water which girdles our globe.

It would be out of place to enter here more minutely into this large subject; and already it may be asked, what connexion has all this with that part of the address that went before it?

There are, however, strong grounds for supposing that the meteorology of the sun and that of the earth are intimately connected together. Mr. Broun has shown the existence of a meteorological period connected apparently with the sun's rotation, five successive years' observations of the barometer at Singapore all giving the period 25·74 days. Mr. Baxendell, of Manchester, was, I believe, the first to show that the convection-currents of the earth appear to be connected somehow with the state of the sun's surface as regards spots; and still more recently Mr. Meldrum, of the Mauritius observatory, has shown, by a laborious compilation of ships' logs, and by utilizing the meteorological records of the island, that the cyclones in the Indian Ocean are most frequent in years when there are most sun-spots. He likewise affords us grounds for supposing that the rainfall, at least in the tropics, is greatest in years of maximum solar disturbance.

M. Poey has found a similar connexion in the case of the West-Indian hurricanes; and, finally, Piazzi Smyth, Stone, Köppen, and, still more recently, Blanford have been able to bring to light a cycle of terrestrial temperature having apparent reference to the condition of the sun.

Thus we have strong matter-of-fact grounds for presuming a connexion between the meteorology of our luminary and that of our planet, even although we are in complete ignorance as to the exact nature of this bond.

If we now turn to terrestrial magnetism the same connexion becomes apparent. Sir Edward Sabine was the first to show that the disturbances of the magnetism of the earth are most violent during years of maximum sun-spots. Mr. Broun has shown that there is likewise a reference in magnetic phenomena to the period of the sun's rotation about his axis, an observation recently confirmed by Hornstein; and still more recently Mr. Broun has shown that the moon has an action upon the earth's magnetism which is not altogether of a tidal nature, but depends, in part at least, upon the relative position of the sun and moon.

I must trust to your forbearance if I now venture to bring forward considerations of a somewhat speculative nature.

We are all familiar with the generalization of Hadley; that is to say, we know there are undercurrents sweeping along the surface of the earth from the poles to the equator, and upper currents sweeping back from the equator to the poles. We are likewise aware that these currents are caused by the unequal temperature of the earth; they are, in truth, convection-currents, and their course is determined by the positions of the hottest and coldest parts of the earth's surface. We may expect them, therefore, to have a reference not so much to the geographical equator and poles as to the hottest and coldest regions. In fact we know that the equatorial regions into which the trade-winds rush and from which the anti-trades take their origin, have a certain annual oscillation depending upon the position of the sun, or, in other words, upon the season of the year. We may likewise imagine that the region into which the upper currents pour themselves is not the geographical pole, but the pole of greatest cold.

In the next place we may imagine that these currents, as far as regards a particular place, have a daily oscillation. This has, I believe, been proved as regards the lower currents or trade-winds, which are more powerful during the day than during the night, and we may therefore expect it to hold good with regard to the upper currents or anti-trades; in fact we cannot go wrong in supposing that they also, as regards any particular place, exhibit a daily variation in the intensity with which they blow.

Again, we are aware that the earth is a magnet. Let us not now concern ourselves about the origin of its magnetism, but rather let us take it as it is. We must next bear in mind that rarefied air is a good conductor of electricity; indeed, according to recent experiments, an extremely good conductor. The return trades that pass above from the hotter equatorial regions to the poles of cold, consisting of moist rarefied air, are therefore to be regarded in the light of good conductors crossing lines of magnetic force; we may therefore expect them to be the vehicle of electric currents. Such electric currents will of course react on the magnetism of the earth. Now, since the velocity of these upper currents has a daily variation, their influence as exhibited at any place upon the magnetism of the earth may be expected to have a daily variation also.

The question thus arises, Have we possibly here a cause which may account for the well-known daily magnetic variation? Are the peculiarities of this variation such as to correspond to those which might be expected to belong to such electric currents? I think it may be said that, as far as we can judge, there is a likeness of this kind between the peculiarities of these two things; but a more prolonged scrutiny will of course be essential before we can be absolutely certain that such currents are fitted to produce the daily variation of the earth's magnetism.

Besides the daily and yearly periodic changes in these upper convection-currents, we should also expect occasional and abrupt changes forming the counterparts of those disturbances in the lower strata with which we are familiar. And these may be expected in like manner to produce non-periodic occasional disturbances of the magnetism of the earth. Now it is well known that such disturbances do occur, and, further, that they are most frequent in those years when cyclones are most frequent—that is to say, in years of maximum sun-spots. In one word, it appears to be a tenable hypothesis to attribute at least the most prominent magnetic changes to atmospheric motions taking place in the upper regions of the atmosphere, where each moving stratum of air becomes a conductor moving across lines of magnetic force; and it was Sir William Thomson, I believe, who first suggested that the motion of conductors across the lines of the earth's magnetic force must be taken into account in any attempted explanation of terrestrial magnetism.

It thus seems possible that the excessive magnetic disturbances which take place in years of maximum sun-spots may not be directly caused by any solar action, but may rather be due to the excessive meteorological disturbances which are likewise characteristic of such years; on the other hand, that magnetic and meteorological influence which Mr. Broun has found to be connected with the sun's rotation points to some unknown direct effect produced by our luminary, even if we imagine that the magnetic part of it is caused by the meteorological. Mr. Broun is of opinion that this effect of the sun does not depend upon the amount of spots on his surface.

In the next place, that influence of the sun in virtue of which we have most cyclones and greater meteorological disturbance in the years of maximum spots, cannot, I think (as far as we know at present), be attributed to a change in the heating-power of the sun. We have no doubt traces of a temperature effect which appears to depend upon the sun-period; but its amount is very small, whereas the variation in cyclonic disturbance is very great. We are thus tempted to associate this cyclone-producing influence of the sun with something different from his light and heat. As far, therefore, as we can judge, our luminary would appear to produce three distinct effects upon our globe:—In the first place, a magnetic and meteorological effect, depending somehow upon his rotation; secondly, a cyclonic effect, depending somehow upon the disturbed state of his surface; and lastly, the well-known light-and-heat effect with which we all are familiar.

If we now turn to the sun, we find that there are three distinct forms of motion which animate his surface-particles. In the first place, each particle is carried round by the rotation of our luminary; secondly, each particle is influenced by the gigantic meteorological disturbances of the surface, in virtue of which it may acquire a velocity ranging as high as 130 or 140 miles a second; and lastly, each particle, on account of its high temperature, is vibrating with extreme rapidity, and the energy of these vibrations communicated to us by means of the etherial medium produces the well-known light-and-heat effect of the sun.

Now, is it philosophical to suppose that it is only the last of these three motions that influences our earth, while the other two produce absolutely no effect? On the contrary, we are, I think, compelled, by considerations connected with the theory of energy, to attribute an influence, whether great or small, to the first two as well as to the last.

We are thus led to suppose that the sun must influence the earth in three ways, one depending on his rotation, another on his meteorological disturbance, and a third by means of the vibrations of his surface-particles.

But we have already seen that, as a matter of fact, the sun does appear to influence the earth in three distinct ways—one magnetically and meteorologically, depending apparently on his period of rotation; a second cyclonically, depending apparently on the meteorological conditions of his surface; and a third by means of his light and heat.

Is this merely a coincidence, or has it a meaning of its own? We cannot tell; but I may venture to think that in the pursuit of this problem we ought to be prepared at least to admit the possibility of a threefold influence of the sun.

Even from this very meagre sketch of one of the most interesting and important of physical problems, it cannot fail to appear that while a good deal has already been done, its progress in the future will very greatly depend on the completeness of the method and continuity of the observations by which it is pursued. We have here a field which is of importance not merely to one, or even to two, but almost to every conceivable branch of research.

Why should we not erect in it a sort of science-exchange into which the physicist, the chemist, and the geologist may each carry the fruits of his research, receiving back in return some suggestion, some principle, or some other scientific commodity that will aid him in his own field?

But to establish such a mart must be a national undertaking, and already several nations have acknowledged their obligations in this respect.

Already the German Government have established a Sonnenwarte, the mere building and equipment of which is to cost a large sum. With an appreciation of what the spectroscope has done for this inquiry, the first directorship was offered to Kirchhoff, and on his declining it, Herr Vogel has been placed in charge. In France also a physical observatory is to be erected at Fontenay, on an equal, if not greater, scale, of which Janssen has already accepted the directorship; while in Italy there are at least three observatories exclusively devoted to this branch of research.

Nor must we forget that in this country the new observatory at Oxford has been so arranged that it can be employed in such inquiries. But what has England as a nation done?

Some years since, at the Norwich Meeting of this Association, a movement was set on foot by Colonel Strange which resulted in the appointment of a Royal Commission on the advancement of science, with the Duke of Devonshire as chairman. This Commission have quite recently reported on the steps that ought, in their opinion, to be taken for the advancement of scientific research.

One of their recommendations is expressed in the following words:—

"Important classes of phenomena relating to physical meteorology and to terrestrial and astronomical physics require observations of such a character that they cannot be advantageously carried on otherwise than under the direction of Government. Institutions for the study of such phenomena should be maintained by the Government; and in particular an observatory should be founded specially devoted to astronomical physics."

If the men of science of this country who procured the appointment of this commission, and who subsequently gave evidence before it, will now come forward to support its recommendations, it can hardly be doubted that these will be speedily carried into effect.

But other things besides observations are necessary if we are to pursue with advantage this great physical problem.

One of these is the removal of the intolerable burden that has hitherto been laid upon private meteorologists and magneticians. Expected to furnish their tale of bricks, they have been left to find their own straw. Nothing more wretched can be imagined than the position of an amateur (that is to say, a man who pursues science for the love of it and is unconnected with any establishment) who has set himself to promote observational inquiries, whether in meteorology or magnetism.

He has first to obtain, with great expenditure of time or money, or both, copies of the individual observations taken at some recognized institution. He has next to reduce these in the way that suits his inquiry, an operation again consuming time and demanding means. Let us suppose all this to be successfully accomplished and a valuable result obtained. It is doubtless embodied in the Transactions of some Society; but it excites little enthusiasm, for it consists of something which cannot be repeated by every one for himself like a new and interesting experiment. Yet the position of such men has recently been improved. Several observatories and other institutions now publish their individual observations; this is done by our Metereological Office, while Dr. Bergsma, Dr. Neumayer, and Mr. Broun are recent examples of magneticians who have adopted this plan. The publication of the work of the latter is due to the enlightened patronage of the Rajah of Travancore, who has thus placed himself in front of the princes of India and given them an example which it is to be hoped they will follow. But this is only one step in the right direction; another must consist in subsidizing private meteorologists and magneticians in order to enable them to obtain the aid of computers in reducing the observations with which they have been furnished. The man of science would thus be able to devote his knowledge, derived from long study, to the methods by which results, and the laws regulating them, are to be obtained; he could be the architect and builder of a scientific structure without being forced to waste his energies on the work of a hodman.

Another hindrance consists in our deficient knowledge as to what observations of value in magnetism and meteorology have already been made. We ought to have an exhaustive catalogue of all that has been done in this respect in our globe, and of the conditions under which the various observations will be accessible to outside inquirers. A catalogue of this kind has been framed by a committee of this Association; but it is confined to the dominions of England, and requires to be supplemented by a list of that which has been done abroad.

A third drawback is the insufficient nature of the present facilities for the invention and improvement of instruments and for their verification.

We have no doubt advanced greatly in the construction of instruments, especially in those which are self-recording. The names of Brooke, Robinson, Welsh, Osler, and Beckley will occur to us all as improvers of our instruments of observation. Sir W. Thomson has likewise adapted his electrometer to the wants of meteorology. Dr. Roscoe has given us a self-recording actinometer; but a good instrument for observing the sun's heat is still a desideratum. It ought likewise to be borne in mind that the standard mercurial thermometer is by no means a perfect instrument.

In conclusion, it cannot be doubted that a great generalization is looming in the distance—a mighty law, we cannot yet tell what, that will reach us, we cannot yet say when. It will involve facts hitherto inexplicable, facts that are scarcely received as such because they appear opposed to our present knowledge of their causes.

It is not possible, perhaps, to hasten the arrival of this generalization beyond a certain point; but we ought not to forget that we *can* hasten it, and that it is our duty to do so. It depends much on ourselves, our resolution, our earnestness, on the scientific policy we adopt, as well as on the power we may have to devote ourselves to special investigations, whether such an advent shall be realized in our day and generation, or whether it shall be indefinitely postponed. If governments would understand the ultimate *material* advantages of every step forward in science, however inapplicable each may appear for the moment to the wants or pleasures of ordinary life, they would find reasons, patent to the meanest capacities, for bringing the wealth of mind, now lost on the drudgery of common labours, to bear on the search for those wondrous laws which govern every movement, not only of the mighty masses of our system, but of every atom distributed throughout space.

MATHEMATICS.

On a Screw-complex of the Second Order.

By Professor R. S. BALL, *LL.D., F.R.S.*

Denoting by $\theta_1, \ldots, \theta_6$ the six coordinates of a screw, then an homogeneous equation of the second degree, $U_\theta = 0$, between the six coordinates denotes what may be termed a screw-complex of the second order. If α be a given screw, then

$$\alpha\frac{dU}{d\theta_1} + \&c. + \alpha_6\frac{dU}{d\theta_6} = 0,$$

being a linear equation in $\theta_1, \ldots, \theta_6$, denotes the locus of screws about which a body which has freedom of the fifth order can be twisted. To this system one screw ϕ is reciprocal; and we may call the screw θ thus defined the polar of the screw α with respect to the screw-complex $U_\theta = 0$. The relation between α and its polar is independent of the screws of reference.

The locus of the screws about which a body can twist so that when it has the unit of twist velocity its kinetic energy is zero is an imaginary screw-complex of the second order. The polar of any screw α with respect to this screw-complex is the screw an impulsive wrench on which would make the body commence to twist about α.

On the Analytical Forms called Factions. By Professor CAYLEY, *F.R.S.*

A faction is a product of differences such that each letter occurs the same number of times; thus we have a quadrifaction where each letter occurs twice, a cubifaction where each letter occurs three times, and so on. A broken faction is one which is a product of factions having no common letter; thus

$$(a-b)^2\,(c-d)\,(d-e)\,(e-c)$$

is a broken quadrifaction, the product of the quadrifactions

$$(a-b)^2 \quad \text{and} \quad (c-d)\,(d-e)\,(e-c).$$

We have, in regard to quadrifactions, the theorem that every quadrifaction is a sum of broken quadrifactions such that each component quadrifaction contains two or else three letters. Thus we have the identity

$$2(a-b)(b-c)(c-d)(d-a) = (b-c)^2 . (a-d)^2 - (c-a)^2 . (b-d)^2 + (a-b)^2 . (c-d)^2,$$

which verifies the theorem in the case of a quadrifaction of four letters; but the verification even in the next following case of a quadrification of five letters is a matter of some difficulty.

The theory is connected with that of the invariants of a system of binary quantics.

On the Theory of Linear Transformations: I. *The Graphical Representation of Invariants*; II. *The Expansion of Unsymmetrical Functions in Symmetrical Functions and Determinants*; III. *The Notation of Matrices.* *By* Professor CLIFFORD, *F.R.S.*

On the Calculus of Motors. By Professor J. D. EVERETT, *F.R.S.E.*

See three articles, entitled "On a new Method in Statics and Kinematics," in the 'Messenger of Mathematics' for 1874 and 1875.

Formulæ of Verification in Partitions. By J. W. L. GLAISHER, *M.A.*, *F.R.S.*

At the Edinburgh Meeting (Report, 1871, Transactions of the Sections, pp. 23–25) Sylvester gave a formula for verifying, in writing down all the partitions of a given number n, that none had been omitted. The formula in question was that

$$\Sigma(1-x+xy-xyz+xyzw-\&c.)=0, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

where in any partition x denotes the number of 1's present, y the number of 2's, z the number of 3's, and the Σ extends to all the partitions; so that $\Sigma 1=\mathrm{N}$, the total number of partitions of n.

In this very elegant formula, however, as the terms are alternately positive and negative, an omission may easily cancel itself; *ex. gr.* if the omitted partition contains one 1 and no 2, it would appear as 1 in the first term, as 1 in the second term, and as zero in the succeeding terms, so that its omission would not be pointed out. It becomes therefore a matter of interest to examine what the formula (1) becomes if all the terms are taken with the positive sign.

I. Starting from the identity

$$1+\frac{t}{1-t}+\frac{t^3}{1-t\,.\,1-t^2}+\frac{t^6}{1-t\,.\,1-t^2\,.\,1-t^3}+\&c.=1+t\,.\,1+t^2\,.\,1+t^3\,.\,.\,.\,,$$

and dividing throughout by $1-t\,.\,1-t^2\,.\,1-t^3\,.\,.\,.$, we have

$$\frac{1}{1-t\,.\,1-t^2\,.\,1-t^3}+\frac{t^3}{(1-t)^2\,.\,1-t^2\,.\,1-t^3\,.\,.\,.}+\frac{t^6}{(1-t)^2(1-t^2)^2\,.\,1-t^3\,.\,.\,.}+\&c.$$

$$=\frac{1+t\,.\,1+t^2\,.\,1+t^3\,.\,.\,.}{1-t\,.\,1-t^2\,.\,1-t^3\,.\,.\,.}$$

$$=(1+2t+2t^2+2t^3+\&c.)\,(1+2t^2+2t^4+\&c.)\,(1+2t^3+2t^6+\&c.)\,.\,.\,.\,;$$

whence, equating the coefficients of t^n,

$$\Sigma(1+x+xy+xyz+xyzw+\&c.)=\Sigma 2^r, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

where r is the number of *different* elements contained in any partition. Thus, take as an example $n=7$: the partitions are

1+1+1+1+1+1+1,
1+1+1+1+1+2,
1+1+1+2+2,
1+1+1+1+3,
1+2+2+2,
1+1+1+4,
1+1+2+3,
1+1+5,
1+2+4,
2+2+3,
1+3+3
1+6
2+5
3+4
7

so that N, the number of partitions, $=15$, $\Sigma x=30$, $\Sigma xy=17$, $\Sigma xyz=2$. Also there are 2 partitions in which only one element occurs, 11 in which two elements occur, and 2 in which three elements occur. Thus Sylvester's formula (1) gives

$$15-30+17-2=0;$$

and (2) gives

$$15+30+17+2 = 2\,.\,2+11\,.\,2^2+2\,.\,2^3.$$

The two formulæ (1) and (2) taken together form a much better verification than either singly; viz. we have

$$\Sigma(1+xy+xyzw+\&c.) = \Sigma(x+xyz+\&c.) = \Sigma 2^{r-1},$$

in which we may replace $\Sigma 2^{r-1}$ by $\Sigma 2^s$, s denoting the *number of changes* in any partition.

The following formulæ afford additional verifications:—

II. From the identity

$$\frac{1-t\,.\,1-t^2\,.\,1-t^3\,\dots}{1+t\,.\,1+t^2\,.\,1+t^3\,\dots} = 1-2t+2t^4-2t^9+\&c.,$$

we have

$$\Sigma \pm 2^{r-1} = 0,\ 1, \text{ or } -1,$$

according as n is not a square, is an even square, or is an uneven square: the sign $+$ is to be used if the partition contains an even number of terms, and the sign $-$ if the number is uneven.

III. From the same identity inverted, viz. from

$$\frac{1+t\,.\,1+t^2\,.\,1+t^3\,\dots}{1-t\,.\,1-t^2\,.\,1-t^3\,\dots} = \frac{1}{1-2t+2t^4-2t^9+\&c.},$$

we have

$$\Sigma 2^r = (-)^n\,(R-R'),$$

where R denotes the number of representations* of n as the sum of an even number of squares, and R′ the number of representations as an uneven number of squares.

To verify these results in the case $n=7$ we have, for II., considering the partitions with an even number of terms,

$$\Sigma 2^{r-1}=6\times 2+1\times 2^2=16;$$

and for the partitions with an uneven number of parts,

$$\Sigma 2^{r-1}=2\times 1+5\times 2+1\times 2^2=16,$$

thus verifying the theorem, since 7 is not a square.

For III. the partitions of 7 as a sum of squares are two, viz.

$$1+1+1+4 \quad \text{and} \quad 1+1+1+1+1+1+1.$$

The former gives rise to 4×16 representations and the latter to 1×128 representations, and the formula becomes

$$64=(-)^7\{4\times 16-128\}.$$

The four theorems taken together, viz.

$$\Sigma(1+xy+\&c.) = \Sigma(x+xyz+\&c.) = \Sigma 2^{r-1} = \tfrac{1}{2}(-)^n(R-R'),$$

with

$$\Sigma \pm 2^{r-1} = 0,\ 1,\ -1,$$

form a striking system of mutually related formulæ of verification.

The author had investigated other systems, but this was the most satisfactory he had met with.

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* See Professor H. J. S. Smith's "Report on the Theory of Numbers," Brit. Assoc. Rep. 1865, p. 337.

Theorems on the n^{th} roots of Unity. By J. W. L. GLAISHER, *M.A.*, *F.R.S.*

If n be any number and if all the sets of r elements that can be formed from the numerals $1, 2, 3 \dots n-1$ be written down according to any rule with regard to sequences and breaks, then the sum of all these sets will always be rational if the numerals $1, 2, 3 \dots n-1$ be supposed to stand for $1-x$, $1-x^2$, $1-x^3 \dots 1-x^{n-1}$, x being any prime nth root of unity.

To make the theorem clear, consider an example. Take $n=7$, and write down all the sets which can be formed from the numerals 1, 2, 3, 4, 5, 6 having (say) a sequence of two and one break (*i. e.* having two numbers consecutive and one non-consecutive or isolated), viz. these are

124, 125, 126, 235, 236, 346, 341, 451, 452, 561, 562, 563;

then the theorem asserts that x being a 7th root of unity, the expression

$$1-x\,.\,1-x^2\,.\,1-x^4 + 1-x\,.\,1-x^2\,.\,1-x^5 + 1-x\,.\,1-x^2\,.\,1-x^6 + \dots$$
$$+ 1-x^5\,.\,1-x^6\,.\,1-x^2 + 1-x^5\,.\,1-x^6\,.\,1-x^3$$

is rational. The simplest case is that of a sequence without any break; *ex. gr.* consider a sequence of two, then, since 12, 23, 34, 45, 56 are the only sets, the theorem asserts that

$$1-x\,.\,1-x^2+1-x^2\,.\,1-x^3+1-x^3\,.\,1-x^4+1-x^4\,.\,1-x^5+1-x^5\,.\,1-x^6$$

is rational.

The general mode of proof will be easily gathered from the demonstration of the truth of the theorem in the case of these two examples. Take the second first, and consider the function of z,

$$(1-z)\,(1-xz), =1+Az+Bz^2, \text{ say,}$$

x being a 7th root of unity. Since 7 is a prime number every root is a prime root, and the roots of the equation $x^7=1$ are x, x^2, x^3, x^4, x^5, x^6, 1; so that, substituting successively these values for z, and adding the results, we see that

$$(1-x)(1-x\,.\,x)+(1-x^2)(1-x\,.\,x^2)+(1-x^3)(1-x\,.\,x^3)+(1-x^4)(1-x\,.\,x^4)$$
$$+(1-x^5)(1-x\,.\,x^5)+(1-x^6)(1-x\,.\,x^6)+(1-x^7)(1-x\,.\,x^7)$$

(the last two terms being zero) is rational, since the coefficients of A and B vanish by the summation.

To prove the theorem in the case of the first example, note that all the sets may be obtained by starting with the three in which the sequence is 12, and continually adding unity to each of the three numbers in each set, thus:

124,	125,	126
235,	236,	237
346,	347,	341
457,	451,	452
561,	562,	563
672,	673,	674
713,	714,	715
124,	125,	126

(in which 8 is replaced by 1 as it arises). We arrive after a cycle of seven lines at the original line again; and, ignoring the terms in which 7 occurs, since $1-x^7=0$, we see that $(1, 2, 3 \dots$ denoting, as stated above, $1-x$, $1-x^2$, $1-x^3 \dots)$ the first column, viz.

$$124 + 235 + 346 + 561,$$

is formed by putting z equal successively to x, x^2, x^3, x^4, x^5, x^6, 1 in the expression $1-z\,.\,1-xz\,.\,1-x^3z$, which is of the form $1+Az+Bz^2+Cz^3$; and similarly for the other columns. It is evident in this example that the three cycles include all the sets which contain a sequence of two and one break; so that the theorem is proved for this case. A little consideration, however, shows too that if all the sets formed according to any fixed rule regulating the sequences and breaks be written down, they must consist of a group (or cycle), or of an aggregation of several groups each of which is rational. For consider any one set: it must belong to a group, for we can obtain a group from it by increasing the numerals in it, each by unity, successively till it reproduces itself; also no set can be common to two groups.

We thus see that the truth of the general theorem depends upon two considerations, viz. (i) upon the remark that any function such as

$$\phi(x, x)+\phi(x, x^2)+\phi(x, x^3)+ \dots \phi(x, x^n),$$

where

$$\phi(x, z)=\mathrm{A}+\mathrm{B}z+\mathrm{C}z^2 \dots +\mathrm{P}z^{n-1}$$

(B, C . . . P being any non-infinite functions of x), is rational; and (ii) upon the proposition that the total series of sets formed by arranging the numerals according to any law of sequences and breaks consists of the aggregation of groups.

It is evident that the theorem is equally true if we understand 1, 2, 3 . . . to mean

$$(1-x)^2,\ (1-x^2)^2,\ (1-x^3)^2, \dots,$$

or even

$$(1-x)^n,\ (1-x^2)^n,\ (1-x^3)^n \dots,$$

or, in fact, any functions

$$\phi(x, x),\ \ \phi(x, x^2) \dots,$$

subject to the conditions that $\phi(x, 1)=0$, and that in the development of the type expression involving z the coefficients of the terms in z^0, z^n, z^{2n} . . . are to be independent of x.

If the former condition is not satisfied, the theorem is still true if the sets are formed from the series of numerals 1, 2, 3 . . . n (*i. e.* including n). With this alteration therefore the theorem is true for

$$1+x,\ 1+x^2 \dots \quad \text{or for} \quad (1+x)^n,\ (1+x^2)^n \dots$$

The point of the theorem lies in the fact that functions of the roots of an equation which are not in appearance symmetrical, are rational; but it is generally quite easy to go further and assign the absolute values of any of the expressions considered, since the value of any group is readily assigned: *ex. gr.* consider the group written above, viz. 124+235+346+561 ; this is

$$\begin{aligned}\Sigma(1-z)(1-xz)(1-x^3z) &= \Sigma\,(1+\mathrm{A}z+\mathrm{B}z^2+\mathrm{C}z^3),\ \text{for } z=x, x^2 \dots x^7\\ &= 7,\end{aligned}$$

and generally each group $=n$ (1, 2 . . . standing for $1-x$, $1-x^2$ . . .), so that the value of an expression = n times the number of groups it contains.

It is also to be noted that very often it is not necessary that x should be a prime nth root; *ex. gr.* in the expression just written it is enough that

$$\Sigma z=0,\ \ \Sigma z^2=0,\ \ \Sigma z^3=0,$$

i. e. that neither x, x^2, nor x^3 should be unity. In this particular instance, since 7 is prime, every root is a prime root; but whatever n may be, if there be only three numerals in each set, it is enough that x is an nth root which is not a square or cube root of unity; and the generalization of this remark is obvious.

On some Geometrical Theorems. *By* W. HAYDEN.

The paper was principally concerned with the properties of an isosceles triangle in which the squares on the equal sides are each double the square on the unequal side obtained geometrically: (1) this triangle can be constructed without the use of the diagonal of a square, as shown in the first proposition; (2) a property of this triangle is that each of its equal angles is equal to $1\frac{1}{2}$ the unequal angle $+\frac{1}{2}$ the angle included by the straight lines joining the unequal angle to the points of trisection of the unequal side; (3) another property is that the unequal angle can be divided into two parts such that the square on the chord of one segment is double the square on the chord of the other segment (a similar property belongs to the isosceles right-angled triangle); (4) the square can be reduced to what may be termed its elementary triangles, eight in number, all the angles having a definite relation.

The paper treats of the properties of this triangle in combination with the circle, the square, circles in geometrical progression, two and three circles, the square and the circumscribing circle, and the ellipse.

Two Memoirs.—I. On the Shadows of Plane Curves on Spheres. II. On Cubic Spherical Curves with triple Cyclic Arcs and triple Foci. By Henry M. Jeffery, *M.A.*

I. On the Shadows of Plane Curves on Spheres *.

1. M. Chasles, in his Geometrical Memoirs on Spherical Conics (which laid the foundation of the subject), has investigated several of their properties from projections of the circles lying in a cyclic plane of the cone.

It was proposed to establish general analytical processes which should embrace these theorems, particularly as that geometer has urged the subject on analysts.

2. The several systems of coordinates in ordinary use were adapted from plane to spherical geometry.

Cartesian coordinates are reduced from gnomonic projection to Gudermann's system, in which the coordinates of a point, whether rectangular or oblique, are tangents of the arcs intercepted on the arcs of reference. From gnomonic projection, Boothian tangential coordinates are represented on the sphere by cotangents of the arcs intercepted on the arcs of reference.

Ex. The focal equation to the plane conic

$$\frac{l}{r} = 1+\epsilon\cos\theta.$$

The equation to its projection on the sphere has the same form,

$$\frac{\tan l}{\tan \rho} = 1 + \frac{\sin 2\gamma}{\sin 2a}\cos\theta;$$

for

$$\epsilon = \frac{\mathrm{A'S}-\mathrm{AS}}{\mathrm{A'S}+\mathrm{AS}} = \frac{\tan\delta'-\tan\delta}{\tan\delta'+\tan\delta} = \frac{\sin(\delta'-\delta)}{\sin(\delta'+\delta)} = \frac{\sin 2\gamma}{\sin 2a},$$

where the symbols have the ordinary acceptation.

The same process was shown to be applicable to determine the analytical forms and geometrical properties of both pole- and polar-spherical curves.

3. Equations to a circle or conic, which are expressed in rectangular coordinates in a cyclic plane of a cone, were converted into three-point tangential equations of the projected spherical curve.

Two points of reference are situated in the cyclic arc, and the third is the polar point of the cyclic arc with respect to the spherical conic. By this process the several properties of the spherical conic which relate to a single cyclic arc are simply deduced from those of the plane circle, in following the geometrical guidance of M. Chasles.

4. Formulæ were next given to express the shadow of a plane curve, as determined by trilinear coordinates, by spherical coordinates.

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* This memoir has been printed *in extenso* in the 'Quarterly Mathematical Journal,' 1875.

If α', β', γ' be the primitive trilinear coordinates of a point referred to a triangle ABC, then if $\sin\alpha$, $\sin\beta$, $\sin\gamma$ denote the spherical coordinates of the projected point referred to a spherical triangle, constituted by planes through the centre O and the sides of ABC,

$$\begin{aligned}\sin\alpha : \sin\beta : \sin\gamma &:: \sin \mathrm{BC} : \sin \mathrm{CA} : \sin \mathrm{AB}\\ &:: \quad ap_1\alpha' \ : \ bp_2\beta' \ : \ cp_3\gamma',\end{aligned}$$

where p_1, p_2, p_3 are the perpendiculars on the opposite faces of the tetrahedron OABC.

If the chords of the arcs of the spherical triangle constitute the sides of the triangle of reference,

$$\alpha' : \beta' : \gamma' :: \cos\frac{a}{2}\sin\alpha : \cos\frac{b}{2}\sin\beta : \cos\frac{c}{2}\sin\gamma.$$

By this process it was shown that the shadow of a circular cubic has the shadow of the line at infinity for a cyclic arc. The shadow of a Cartesian, which has cusps at the circular points at infinity, has two (and may have three) coincident cyclic arcs in the shadow of the line at infinity.

5. Formulæ were given to determine the tangential equation of the shadow on a sphere of a plane curve, which is itself expressed by tangential coordinates:

$$\begin{aligned}p' : q' : r' &:: \mathrm{OA}\sin p : \mathrm{OB}\sin q : \mathrm{OB}\sin r\\ &:: p_1 \sin a \sin p : p_2 \sin b \sin q : p_3 \sin c \sin r.\end{aligned}$$

In the particular case where OA, OB, OC are equal, the formulæ of transformation are identical in form.

These formulæ were applied to deduce equations to spherical curves, and in particular to investigate the projections of the circular points at infinity, and their properties.

6. This outline of the doctrine of projection on the sphere may be regarded as a separate chapter in spherical analytical geometry, and may suggest further developments of the subject by following the lead of the great French geometer.

II. On Cubic Spherical Curves with triple Cyclic Arcs and triple Foci.

1. *On the classification of cubic cones and spherical cubics.*—There are five cubic cones—simplex, complex, crunodal, acnodal, and cuspidal, to use the nomenclature of Prof. Cayley. The singular and non-singular forms have been studied in the canonical and other distinct equations.

It is here proposed to classify them according to their cyclic planes or arcs—(1) with three single cyclic arcs, (2) one double and another single, and (3) with a triple cyclic arc. The classification of Newton and Plucker for plane cubics will thus be imitated; but the number of groups is much less, viz. three in all.

As there are three real foci in a plane curve of the third class, it is inferred that there are three real foci in a spherical cubic of the same class, since the tangential equations to both are identical in form; hence, by reciprocation, there are three cyclic planes in a cubic cone of the third order. The three groups may be conveniently studied in trilinear equations:—

$$\begin{aligned}&(1) \quad \kappa\alpha\beta\gamma = l\alpha+m\beta+n\gamma,\\ &(2) \quad \kappa\alpha^2\beta \ = \gamma,\\ &(3) \quad \kappa\alpha^3 \ \ = \beta,\end{aligned}$$

where κ is the variable perimeter in each group. The left-hand side defines the cyclic arcs, the right-hand the satellite arc. The symbols denote the sines of the respective arcs. If the variables be interpreted as tangential coordinates, these three groups represent all cubics of the third class both plane and spherical—viz. (1) with three single foci, (2) with one double and one single focus, (3) with one triple focus.

As this investigation has a double interest, it is desirable that the five cubic cones of the third class should have distinctive names*.

2. *On the cubic referred to a triple cyclic arc.*—Let the triple cyclic arc and its satellite include any angle c; since the third arc of reference is arbitrary, assume it to be the quadrantal polar of the intersection of the other two.

The trilinear equation to this group is

$$\kappa a^3+3\beta(4n^2)=0, \text{ where } (4n^2) \text{ denotes } a^2+\beta^2+c^2\gamma^2+2a\beta\cos c,$$

the expression for six times the volume of the plane tetrahedron formed by the centre of the sphere and the vertices of the spherical triangle of reference. (The symbols may denote the sines of the arcs in question) It is seen that the cubics of this group have a diametral arc and a Newtonian centre at the point of inflexion.

3. *All cubics with triple cyclic arcs have triple foci.*—The equivalent tangential equation to these cubics denotes in general curves of the sixth class,

$$9\kappa^2r^2(q^2+r^2)^2+32\kappa(pq+r^2\cos c)^3-36\kappa(p^2+r^2)(q^2+r^2)(pq+r^2\cos c)$$
$$+12(p^2+r^2)^2(p^2+q^2+c^2r^2-2pq\cos c)=0.$$

This equation may be arranged to exhibit the triple focus

$$(p-q\cos c)^3\{9\kappa^2(2pq\cos c-p^2-q^2)(p-q\cos c)-4\kappa(q-p\cos c)^3\}$$
$$+(p^2+q^2+c^2r^2-2pq\cos c)u_4=0.$$

4. *If the non-singular cubics of this group be complex, all six real foci are situated on the diametral arc; if simplex, only four.*—After removing the factor which denotes the triple focus from the preceding tangential equation, the remaining factor denotes three other foci,

$$9\kappa(2pq\cos c-p^2-q^2)(p-q\cos c)-4(q-p\cos c)^3.$$

Its discriminant will be found to be the same as that of the given cubic equation to the curve. Hence follows the truth of the proposition.

5. *Critic centres in the general case.*—Plucker has defined them for plane cubic curves as middle points, irrespective of their being the sites of nodes.

A plane cubic of a particular group intersects the lines of reference in three collinear fixed points: the locus of the middle point of a straight line through one of these points, intercepted between the other two lines of reference, is a hyperbola; the intersection of three such hyperbolæ determines the critic centres.

The same definition is applicable to spherical cubics.

In particular, if ($\kappa a\beta\gamma=la+m\beta+n\gamma$) denote a spherical cubic of the first group referred to three rectangular arcs of reference, the critic centres determined by this definition are the intersections of three non-singular complex cubics with concurrent cyclic arcs,

$$\frac{-a^2+\beta^2+\gamma^2}{la}=\frac{a^2-\beta^2+\gamma^2}{m\beta}=\frac{a^2+\beta^2-\gamma^2}{n\gamma}.$$

6. *Critic centres of cubics with triple cyclic arcs.*—They are two in number, and lie in the quadrantal polar of the intersection of the point of inflexion. At a critic centre,

$$\frac{df}{da}=0,\quad \frac{df}{d\beta}=0,\quad \frac{df}{d\gamma}=0.$$

Hence the equation of § 2 yields these data,

$$\gamma=0 : \kappa a^2+2a\beta+2\beta^2\cos c=0 : a^2+4a\beta\cos c+3\beta^2=0.$$

It appears from the last equation, thus arranged,

$$(a+2\beta\cos c)^2-\beta^2(1-4\sin^2 c)=0,$$

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* They might be distinguished as simplex or unipartite, complex or bipartite, veribitangential, acubitangential, and inflexional.

that for values of c between 30° and 150° the curve is simplex, and there is no nodal point.

In particular, if the cyclic arc and its satellite are at right angles to each other, the cubic is simplex and trilateral or campaniform.

At the terminal values, $c=\pm 30°$, the cubic is cuspidal, and will be separately considered.

If $4\cos^2 c>3$, the cubic may have all four forms, according to the value of the parameter κ.

The transition from the simplex to complex genera takes place at the critic centres. The discriminant $(64\,S^3-T^2)$ varies as

$$\left\{3\kappa-\frac{2\cos c}{3}\left(9-8\cos^2 c\right)\right\}^2-\frac{4}{9}\left(4\cos^2 c-3\right).$$

The cubic is complex, nodal, or simplex, as the discriminant $> = <0$.

Ex. $\cos c=\frac{5}{4\sqrt{2}}$: the conditions become

$$\left(\kappa-\frac{3}{4\sqrt{2}}\right)\left(\kappa-\frac{7}{9\sqrt{2}}\right)> = <0.$$

Between the limits of $\frac{27}{36\sqrt{2}}$ and $\frac{28}{36\sqrt{2}}$ for κ the discriminant is positive and the curve is complex; at the former limit acnodal, at the latter crunodal, beyond these limits simplex.

In particular, if $\kappa=\frac{2\sqrt{2}}{5}$, the invariant $S=0$, and the curve is simplex neutral.

7. *Cuspidal forms.*—At a cusp both invariants S', T are equal to zero. Hence

$$1=2\kappa\cos c \; : \; 3\kappa^2-6\kappa\cos c+2=0.$$

In this case

$$\kappa=\pm\frac{1}{\sqrt{3}}, \quad c=30° \text{ or } 150°.$$

The corresponding trilinear equations exhibit the cusps

$$\left(\frac{\alpha}{\sqrt{3}}+\beta\right)^3+\frac{\beta\gamma^2}{4}=0, \qquad (c=30°), \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

$$\left(-\frac{\alpha}{\sqrt{3}}+\beta\right)^3+\frac{\beta\gamma^2}{4}=0, \qquad (c=150°). \quad . \quad . \quad . \quad . \quad . \quad . \quad (2)$$

In (1) the cusp is 30° distant from A and 60° from B; in (2) it is 30° from A and 120° from B, and intermediate.

8. By dualizing, corresponding theorems may be obtained for cubics of the third class with triple foci and triple cyclic arcs. The properties of plane cubics of this class may be deduced, although, as in cubics of the third order, they are not co-extensive.

There are three species only *in plano* of trifocal cubics (complex, bitangential, and simplex), whereas all five occur in trifocal spherical cubics. Plane trifocal cubics exhibit (in their point-equations) cusps at infinity, but have not coincident asymptotes.

9. The other two groups of spherical cubics are reserved for future consideration.

Elementary Solution of Huyghens's Problem on the Impact of Elastic Balls.

By PAUL MANSION, *Professor in the University of Ghent.*

1. If two positive quantities x, $=r-z$, and y have a constant product r^2, their sum,

$$r-z+\frac{r^2}{r-z}=2r+\frac{z^2}{r-z},$$

is the smallest possible when $z=0$, viz. when $x=y=r$.

If we consider any number of quantities, say four, whose product $xyzu$ is equal to a constant p, their sum, $S_1=x+y+z+u$, is the smallest possible when they are all equal; for if two of the quantities are unequal, we can diminish their sum S_1 by replacing each by the square root of their product. From these well-known principles we can deduce the solution of a celebrated question, known as Huyghens's problem, as follows:—

2. The sums of the products of these quantities, taken two and two and three and three, viz.

$$S_2=xy+xz+xu+yz+yu+zu, \quad S_3=xyz+xyu+xzu+yzu,$$

are composed of terms which, multiplied together, give a constant product p_3. S_2 and S_3 will therefore have their smallest possible values when the terms are equal, viz. when $x=y=z=u$.

3. The product,

$$P=(1+x)(1+y)(1+z)(1+u), \quad \text{which } =1+S_1+S_2+S_3+p,$$

is the least possible when $x=y=z=u$, because then S_1, S_2, S_3 have their minima values.

4. The expression

$$H=\frac{aXYZ}{(a+X)(X+Y)(Y+Z)(Z+b)},$$

in which a and b are constants and X, Y, Z variables, can be written

$$\frac{1}{\left(1+\frac{X}{a}\right)\left(1+\frac{Y}{X}\right)\left(1+\frac{Z}{Y}\right)\left(1+\frac{b}{Z}\right)};$$

and the greatest value of H, or the least value of the denominator of the expression last written, corresponds to

$$\frac{X}{a}=\frac{Y}{X}=\frac{Z}{Y}=\frac{b}{Z},$$

for the product

$$\frac{X}{a}\cdot\frac{Y}{X}\cdot\frac{Z}{Y}\cdot\frac{b}{Z}=\frac{b}{a}$$

is constant.

5. The preceding argument can evidently be extended to any number of variables. We are led to seek the maximum of a quantity analogous to H and containing n variables in treating the well-known question (Huyghens's):—"Let there be any number of perfectly elastic balls ranged in a straight line; the first strikes the second with a given velocity, the second with the velocity communicated by the first strikes the third, the third strikes the fourth, and so on. The masses a and b of the first and the last being given, determine the masses of the intermediate balls that the last may receive the maximum velocity." M Picart has treated this question by means of the differential calculus ('Nouvelles Annales de Mathématiques,' 1874, pp. 212–219); but the investigation is long. The mathematicians who had solved it previously (Huyghens, Lagrange, &c.) have, he states, only demonstrated that H was really a maximum in the case of three balls. The present note contains a simple and complete solution by means only of elementary algebra.

On the singular Solutions of Differential Equations of the First Order which represent Lines at Infinity. By PAUL MANSION, *Professor in the University of Ghent.*

1. The following is a *résumé* of the theory of singular solutions of differential equations of the first order.

(I.) If a differential equation,

$$f(x, y, y')=0, \quad \text{or} \quad \phi(x, y, x')=0, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (1)$$

has no general integral, it will only happen *exceptionally* that it will have a singular solution. When this singular solution exists, we have simultaneously the three relations

$$f=0,\quad \frac{dy}{dy'}=0,\quad \frac{\delta f}{\delta x}+\frac{\delta f}{\delta y}y'=0, \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (A)$$

or

$$\phi=0,\quad \frac{dx}{dx'}=0,\quad \frac{\delta\phi}{\delta x}x'+\frac{\delta\phi}{\delta y}=0. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (B)$$

for the values of x and y which satisfy the singular solution *.

(II.) If the equation (1) has a general integral,

$$F(x,y,c)=0; \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (2)$$

the singular solutions are given by the elimination of c between the relations

$$\left[F=0,\quad \frac{dy}{dc}=0\right], \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (3)$$

or

$$\left[F=0,\quad \frac{dx}{dc}=0\right], \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (4)$$

or by the systems

$$\left[f=0,\quad \frac{dy}{dy'}=0\right] \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (5)$$

or

$$\left[\phi=0,\quad \frac{dx}{dx'}=0\right], \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (6)$$

equivalent to (3) and (4), unless we have

$$\frac{d^2y}{dxdc}=0 \text{ or } \infty, \quad \text{or } \frac{d^2x}{dydc}=0 \text{ or } \infty. \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \qquad (7)$$

Besides, *in general*, the two equations (5) or (6) have as a consequence the third equation (A) or (B), contrary to what takes place in the first case †.

2. M. Darboux, to whom is due the subdivision of the subject as indicated above, has given several examples where the rule II. seems to fail. We shall show that this is not the case if we introduce *in the infinitesimal analysis* the notion of singular solutions situated wholly at infinity.

(I.) The differential equation

$$y'^2-\frac{9}{4}x=0, \quad \text{or } x-\frac{4}{9x'^2}=0,$$

has for its general integral

$$(y-c)^2-x^3=0, \quad \text{or } x-(y-c)^{\frac{2}{3}}=0.$$

The system (5) cannot give a singular solution. The system (6) leads to $x=0$, which does not satisfy the equation, as it belongs to the case of exception (7), viz. $\frac{d^2x}{dydc}=\infty$; the system (6) is not equivalent to (4). The latter gives

$$\frac{dx}{dc}=\frac{-2}{3(y-c)^{\frac{1}{3}}}=-\frac{2}{3\sqrt{x}}=0,$$

viz. $x=\infty$. Now $x=\infty$ is really a tangent to the cubic $(y-c)^2-x^3=0$, as is immediately evident.

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* Darboux, 'Comptes Rendus,' t. lxx. pp. 1329–1333; Catalan, 'Comptes Rendus,' t. lxxi. pp. 50–57; Darboux, ibid. pp. 267–270; 'Bulletin des Sciences Mathématiques et Astronomiques,' t. iv. pp. 158–176.

† P. Mansion, 'Bulletin de Bruxelles' (2), t. xxxiv. pp. 149–167; Gilbert, ibid. pp. 142–145; P. Mansion, 'Bullettino de Boncompagni,' t. vi. pp. 283–285 (Luglio, 1873).

(II.) The differential equation

$$y'^2+2xy'-y=0, \quad \text{or} \quad 1+2xx'-yx'^2=0,$$

has for its general integral

$$(3yx+2x^3+c)^2-4(y+x^2)^3=0.$$

Putting, for simplicity,

$$y+x^2=z^2, \quad 3yx+2x^3+c=2z^3,$$

we find

$$-\frac{dy}{dc}=\frac{2(3yz+2x^3+c)}{6x(3yz+2x^3+c)-12(y+x^2)^2}=\frac{1}{3(x-z)},$$

$$-\frac{dx}{dc}=\frac{2(3yx+2x^3+c)}{6(y+2x^2)(3yx+2x^3+c)-24x(y+x^2)^2}=\frac{1}{3(x-z)^2},$$

and consequently

$$x'=\frac{dx}{dy}=\frac{1}{x-z}. \quad \ldots\ldots\ldots\ldots \quad (8)$$

The systems (5) and (6) lead to the relation $y+x^2=0$, which is not a singular solution, as it also belongs to the case of exception (7). But the systems (3) and (4) lead to

$$z-x=\infty, \quad \text{or} \quad \sqrt{y+x^2}-x=\infty, \quad \ldots\ldots\ldots \quad (9)$$

a relation which is *in a certain sense* a singular solution of the given equation. To show this, put

$$\sqrt{y+x^2}-x=\mathrm{A}, \quad \text{or} \quad y=2\mathrm{A}x+\mathrm{A}^2,$$

and we deduce

$$x'=\frac{1}{2\mathrm{A}}.$$

On the other hand, the curves represented by the general integral have, after (8), for the coefficient of the direction of their tangent

$$x'=-\frac{1}{\mathrm{A}}.$$

If A increases indefinitely, these two values of x' tend towards the common limit zero. In a certain sense, therefore, the equation (9) represents a singular solution of the given equation.

These two examples are sufficient to explain the apparent exceptions to rule II., which we may consequently regard as giving all the singular solutions which are not at the same time particular integrals.

On Singular Solutions. *By* Professor HENRY J. STEPHEN SMITH, *F.R.S.*

On the Effect of Quadric Transformation on the Singular Points of a Curve. *By* Professor HENRY J. STEPHEN SMITH, *F.R.S.*

Note on Continued Fractions. *By* Professor HENRY J. STEPHEN SMITH, *F.R.S.*

Contributions to the Mathematics of the Chessboard. *By* H. MARTYN TAYLOR, *M.A., Fellow and Tutor of Trinity College, Cambridge.*

The object of the paper was to ascertain the relative values of the pieces on a chessboard. If a piece be placed on a square of a chessboard, the number of squares it commands depends in general on its position. If we calculate the average number of squares which any particular piece commands when placed in succession on every square of the board, it seems fair to assume that this gives a not very inexact measure of the value of the piece.

For special reasons the above problem is stated in the following manner:—"A king and a piece of different colours are placed at random on two squares of a chessboard of n^2 squares: it is required to find the chance that the king is in check." The ordinary chessboard has an even number of squares; and as some of the results take different forms for odd and even values of n, the results are here given merely for even values of n, and the results for the ordinary chessboard of sixty-four squares deduced from them. As the relative values of the knight and bishop on the ordinary chessboard on this hypothesis come out in a ratio very different from the ratio that is ordinarily received by chess-players, it occurred to the author to investigate the chance that when a king and a piece of different colours were placed at random on two squares of a board, the king should be in check but unable to take the piece. This check is called *safe* check in distinction to a mere check, which may be safe or unsafe, which is called *simple* check.

Simple check from one rook.—A rook on any position checks $2(n-1)$ squares. The king can be placed on n^2-1 squares for any given position of the rook. The chance of check, therefore, is $\frac{2(n-1)}{n^2-1} = \frac{2}{n+1}$. If $n=8$, the chance $= \frac{2}{9}$.

Safe check from one rook.—If the rook be on a corner square, it could be taken by a king in check on two squares, and so on. The number of safe checks by a rook on the different squares is given by the following scheme:—

a	*b*	*b*	
b	*c*	*c*	
b	*c*	*c*	

Rook on	Number of safe checks.	Number of such positions of the rook.
a	$2n-4$	4
b	$2n-5$	$4(n-2)$
c	$2n-6$	$(n-2)^2$

The chance

$$= \frac{4(2n-4)+4(n-2)(2n-5)+(n-2)^2(2n-6)}{n^2(n^2-1)} = \frac{2(n-2)}{n(n+1)}.$$

When $n=8$, the chance $= \frac{1}{6}$.

Simple check with one knight.—The number of squares attacked by a knight placed on any square of a chessboard is given by the following scheme:—

a	*b*	*c*	*c*	
b	*c*	*d*	*d*	
c	*d*	*e*	*e*	
c	*d*	*e*	*e*	

Knight on	Number of checks.	Number of such positions of knight.
a	2	4
b	3	8
c	4	$4(n-3)$
d	6	$4(n-4)$
e	8	$(n-4)^2$

The chance of check

$$= \frac{2.4+3.8+4.4(n-3)+6.4(n-4)+8(n-4)^2}{n^2(n^2-1)} = \frac{8(n-2)}{n^2(n+1)}.$$

If $n=8$, chance $= \frac{1}{12}$. For a knight all checks are safe checks.

The above two cases, which are the simplest, will suffice to show the method pursued by the author. In the case of the bishop, n being even, the numerator of the chance fraction is equal to twice the sum of the first $\frac{1}{2}n$ terms of the series

$$(n-1)(n-1)+(n+1)(n-3)+(n+3)(n-5)+\&c. = \tfrac{2}{3}n(n-1)(2n-1).$$

The results for the cases of n even are given in the following Table:—

Chance of the king being in check.

	For board of n^2 squares.		For board of 64 squares.	
	Simple check.	Safe check	Simple check.	Safe check.
Knight	$\frac{8(n-2)}{n^2(n+1)}$	$\frac{8(n-2)}{n^2(n+1)}$	$\frac{1}{12}$	$\frac{1}{12}$
Bishop........	$\frac{2}{3}\,\frac{2n-1}{n(n+1)}$	$\frac{2}{3}\,\frac{(n-2)(2n-3)}{n^2(n+1)}$	$\frac{5}{36}$	$\frac{13}{144}$
Rook	$\frac{2}{n+1}$	$\frac{2(n-2)}{n(n+1)}$	$\frac{2}{9}$	$\frac{1}{6}$
Queen	$\frac{2}{3}\,\frac{5n-1}{n(n+1)}$	$\frac{2}{3}\,\frac{(n-2)(5n-3)}{n^2(n+1)}$	$\frac{13}{36}$	$\frac{37}{144}$
Two bishops ..	$\frac{2}{3}\,\frac{4n^2-9n+2}{n(n^2-2)}$		$\frac{1}{4}$	
Two rooks	$\frac{2(2n^2-2n-1)}{(n+1)(n^2-2)}$		$\frac{37}{93}$	

It is to be remarked that the relative values of the knight, bishop, rook, and queen are, according as we measure them by the chance of simple check or of safe check, on the ordinary chessboard in the ratio of 3, 5, 8, 13, and 12, 13, 24, 37 respectively; while the values of the pieces in the same order, as given by Staunton in the 'Chess-Players' Handbook,' are 3·05, 3·50, 5·48, and 9·94, the value of the pawn being taken as unity. (The value of a pawn depends so much on the fact that it is possible to convert it into a queen, that the method explained in the paper does not appear applicable to it.)

On Laplace's Process for determining an Arbitrary Constant in the Integration of his Differential Equation for the Semidiurnal Tide. By Sir W. Thomson, *F.R.S., F.R.S.E.*

*General Integration of Laplace's Differential Equation of the Tides**. By Sir W. Thomson, *F.R.S., F.R.S.E.*

On the Integration of Linear Differential Equations with Rational Coefficients. By Sir W. Thomson, *F.R.S., F.R.S.E.*

On some Effects of Laplace's Theory of Tides. By Sir W. Thomson, *F.R.S., F.R.S.E.*

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* Published *in extenso* in the 'Philosophical Magazine' for November 1875, ser. 4, vol. l. p. 388.

ASTRONOMY.

On the Total Solar Eclipse of April 5, 1875, *observed at Bangchallô (Siam). By* Dr. J. JANSSEN.

Dr. Janssen used a special telescope for the study of the corona. The results obtained by the observations are as follows:—

1. It was established that the line 1474 is infinitely more pronounced in the corona than in the protuberances. This line seems even to stop abruptly at the edge of the protuberances without penetrating them. The light, therefore, which this line 1474 gives belongs especially to the corona. This observation is one of the strongest evidences that can be brought forward to prove that the corona is a real object, matter radiating by itself. The existence of a solar atmosphere situated beyond the chromosphere (an atmosphere that Dr. Janssen had recognized in 1871 and proposed to call the coronal atmosphere) thus receives confirmation.

2. *Height of the Coronal Atmosphere.*—In 1871 Dr. Janssen announced that the coronal atmosphere extended from a distance of half the sun's radius to the distance of a whole radius at certain points. This assertion has been confirmed not only by the direct observation of the phenomenon, but also by photography. At Dr. Janssen's request, Dr. Schuster took photographs of the corona with exposures of one, two, four, and eight seconds. In this series of photographs the height of the corona increases with the time of exposure. The height of the corona in the eight-seconds' photograph exceeds at some points the sun's radius. (It is true that account ought to be taken of the influence of the terrestrial atmosphere.)

3. As the sky was not perfectly clear at Bangchallô, Dr. Janssen was enabled to observe phenomena that explain previous observations of eclipses which seemed to invalidate the existence of the corona as an incandescent gaseous medium.

On the whole the observations of April 5, 1875, have advanced us a fresh step in the knowledge of the corona by bringing forward new proofs of the existence of an atmosphere round the sun, principally gaseous, incandescent, and very extended.

List of Meteors observed at Oxford. By the Rev. R. MAIN, *F.R.S.*

Transit of Venus, December 8, 1874.

By the Rev. S. J. PERRY, *F.R.S., F.R.A.S.*

The remarks made referred mostly to the Kerguelen Expedition, of which the author had the charge.

Some of the members of this Expedition left England on May 20, and the rest on June 20, 1874. All met at the Cape of Good Hope, and proceeded thence in two of H.M. vessels, the 'Volage' (Captain Fairfax, R.N.) and the 'Supply' (Captain Inglis, R.N.). The Crozets were passed with fair wind and weather; but a storm encountered off Kerguelen delayed the landing for two days. During this time many of the sheep, goats, and oxen, and other live stock taken on board at the Cape were destroyed, and a large boat carried off by the waves. No injury was sustained by the instruments, except the deck thermometers, and no lives were lost.

A few days were spent in surveying the west and south coasts of Royal Sound, and two excellent stations were found by the aid of Captain Bailey, of the sealing schooner 'Emma Jane.' The huts and instruments were erected at once at the principal station, and three weeks later at the second station. A third station was occupied a few days before the transit, as it was found to be perfectly impracticable to attempt observations at MacDonald Island.

The weather generally was not so bad as we had been led to expect; but we were visited by snow-storms even in the middle of summer, and the wind blew half a gale at least five days out of every seven. Still we were free from mist, and the sky was fairly fine during at least part of most days.

On the morning of the transit the preparations were all complete, and every assistance was rendered to the astronomers by Captain Fairfax and Captain Inglis and the other officers. At Stations 2 and 3 excellent results were obtained at ingress; but a cloud prevented internal contact being obtained at Station 1. During the progress of the transit a few photographs, and some measures with the double-image micrometer, were taken at Station 1, clouds, however, interfering with continuous work. At egress both internal and external contact were observed at Stations 1 and 3.

Considering the position of the Island of Desolation, these results were considered satisfactory, and the determination of the longitude was pursued with all possible energy. A most successful chronometer-run had been made from the Cape of Good Hope under the direction of Lieut. C. Corbet, R.N., who also connected the three British Stations in Kerguelen with those of America and Germany; but as the longitude must depend mainly on lunar observations, no opportunity was lost of observing the moon. An altazimuth, especially designed by Sir G. B. Airy for Kerguelen, procured for the longitude ninety double observations of the moon's azimuth or zenith-distance; whilst the transit gave nineteen meridian passages of the moon, and the equatorial one occultation.

In the mean time the observers carried on a very complete series of meteorological and magnetic observations, which were continued during the homeward journey, and the Rev. A. E. Eaton studied the natural history of the island.

Goats and rabbits were left on the island to propagate.

On February 26th the lunar observations were considered sufficient to secure a fundamental longitude; and, provisions running short, in less than two hours after the last meridian observation of the moon H.M.S. 'Volage' and 'Supply' were on their way, one to Ceylon, the other to the Cape.

About a week after leaving the Island of Desolation H.M.S. 'Volage' encountered a cyclone, which might have ended unfortunately for the observers, though their observations were secured by being sent home in duplicate on board H.M.S. 'Supply' and the 'Monongahela,' U.S.N.

The other Government Expeditions were sent to the Sandwich Islands, to New Zealand, Egypt, and Rodriguez; and all were successful except New Zealand, where only a few micrometric measures were obtained.

The Stations in India and Australia, Lord Lindsay at Mauritius, and other private observers were also fairly fortunate; so that we may hope that England will aid largely towards the accurate determination of the solar parallax.

LIGHT, HEAT, AND ELECTRICITY.

On the Ratio of the Actinic Power to the Illuminating Power of the Magneto-Electric Light. *By* Capt. W. DE W. ABNEY, *R.E., F.C.S., F.R.A.S.*

In some recent experiments with magneto-electric machines driven at varying speeds, and consequently with varying engine-power, the author obtained photometric measurements, by optical and also photographic means, of the different intensities of the light produced.

At first sight a discrepancy seemed to arise between the results obtained from the two distinct methods. When, however, the values were laid down graphically, showing the power of the lights in comparison with the work expended in their production, the resulting curves became interesting; they showed that the actinic power of the light diminished much more rapidly than the optical power as the "work done" decreased.

The results of the experiments also showed that there is a certain point for each machine beyond which it is wasteful to increase the motive power, the increase in optical or actinic value of the light being very small.

On Mirage at Sea. *By* Dr. J. JANSSEN.

Many facts relating to the phenomena of mirage at sea are already known; but the author has paid great attention to these appearances in all his voyages since 1868, and has made some remarkable observations on mirage, especially at sunrise and sunset. He has established:—1. That the mirage is nearly constant at the surface of the sea. 2. That the appearances can be explained by assuming the existence of a plane of total reflection, situated at a certain height above the sea. 3. That the phenomena are due to the thermic and hygrometric action of the sea upon the neighbouring atmospheric strata. 4. That there exist at sea direct, inverse, lateral, and other mirages. 5. That these phenomena have a very general influence upon the apparent height of the sea-horizon, which is sometimes lowered, sometimes raised.

This variation of the apparent horizon it is very important to take into account, if we consider the use made of the horizon in nautical astronomy.

On the Photographic Revolver, and on the Observations of the Transit of Venus made in Japan. By Dr. J. JANSSEN.

The author's expedition to Japan to observe the transit of Venus divided into two parts, the one taking up its station at Nagasaki and the other at Kobí.

At Nagasaki he observed the transit with an equatorial of 8 inches aperture. 1. He obtained the two interior contacts. 2. He saw none of the phenomena of the drop or of the ligament; the appearances were geometrical. 3. He observed facts which prove the existence of an atmosphere to Venus: he saw the planet Venus before its entry on the sun's disk by the aid of suitable coloured glasses. This important observation proves the existence of the *coronal atmosphere.* 5. There was taken at Nagasaki a plate by the revolver for the first interior contact. 6. M. Tisserand observed the two interior contacts with a 6-inch equatorial; the contacts were sensibly geometrical. 7. Sixty photographs of the transit upon silvered plates were obtained. 8. There were also obtained some photographs of the transit (wet collodion and albumenized glass).

At Kobí (weather magnificent).—Fifteen good photographs of the transit (wet collodion and albumenized glass), of about 4 inches in size, were obtained: they will admit of being combined with the English photographs at the southern stations. The astronomical observations of the transit were made successfully by M. Delacroix, who was provided with a 6-inch telescope. He observed facts which attest the existence of an atmosphere round Venus.

On a Mode of producing a sharp Meridian Shadow. *By* A. MALLOCH.

On the Optical Properties of a Titano-Silicic Glass. *By* Professor STOKES *and* J. HOPKINSON.

At the Meeting of the Association at Edinburgh in 1871, Professor Stokes gave a preliminary account of a long series of researches in which the late Mr. Vernon Harcourt had been engaged on the optical properties of glasses of a great variety of composition, and in which, since 1862, Professor Stokes had cooperated with him[*]. One object of the research was to obtain, if possible, two glasses which should achromatize each other without leaving a secondary spectrum, or a glass which should form with two others a triple combination, an objective composed of which should be free from defects of irrationality, without requiring undue curvature in the individual lenses. Among phosphatic glasses, the series in which Mr. Harcourt's experiments were for the most part carried on, the best solution of this problem was offered by glasses in which a portion of the phosphoric was replaced by titanic acid. It was found, in fact, that the substitution of titanic for

[*] Report for 1871, Transactions of the Sections, p. 38.

phosphoric acid, while raising, it is true, the dispersive power, at the same time produces a separation of the colours at the blue as compared with that at the red end of the spectrum, which ordinarily belongs only to glasses of a much higher dispersive power. A telescope made of disks of glass prepared by Mr. Harcourt was, after his death, constructed for Mrs. Harcourt by Mr. Howard Grubb, and was exhibited to the Mathematical Section at the late Meeting in Belfast. This telescope, which is briefly described in the 'Report'*, was found fully to answer the expectations that had been formed of it as to destruction of secondary dispersion.

Several considerations seemed to make it probable that the substitution of titanic acid for a portion of the silica in an ordinary crown glass would have an effect similar to what had been observed in the phosphatic series of glasses. Phosphatic glasses are too soft for convenient employment in optical instruments; but should titano-silicic glasses prove to be to silicic what titano-phosphatic glasses had been found to be to phosphatic, it would be possible, without encountering any extravagant curvatures, to construct perfectly achromatic combinations out of glasses having the hardness and permanence of silicic glasses; in fact the chief obstacle at present existing to the perfection of the achromatic telescope would be removed, though naturally not without some increase to the cost of the instrument. But it would be beyond the resources of the laboratory to work with silicic glasses on such a scale as to obtain them free from striæ, or even sufficiently free to permit of a trustworthy determination of such a delicate matter as the irrationality of dispersion.

When the subject was brought to the notice of Mr. Hopkinson he warmly entered into the investigation; and, thanks to the liberality with which the means of conducting the experiment were placed at his disposal by Messrs. Chance Brothers, of Birmingham, the question may perhaps be considered settled. After some preliminary trials, a pot of glass free from striæ was prepared of titanate of potash mixed with the ordinary ingredients of a crown glass. As the object of the experiment was merely to determine, in the first instance, whether titanic acid did or did not confer on the glass the unusual property of separating the colours at the blue end of the spectrum materially more, and at the red end materially less, than corresponds to a similar dispersive power in ordinary glasses, it was not thought necessary to employ pure titanic acid; and rutile fused with carbonate of potash was used as titanate of potash. The glass contained about 7 per cent. of rutile; and as rutile is mainly titanic acid, and none was lost, the percentage of titanic acid cannot have been much less. The glass was naturally greenish, from iron contained in the rutile; but this did not affect the observations, and the quantity of iron would be too minute sensibly to affect the irrationality.

Out of this glass two prisms were cut. One of these was examined as to irrationality by Professor Stokes, by his method of compensating prisms, the other by Mr. Hopkinson, by accurate measures of the refractive indices for several definite points in the spectrum. These two perfectly distinct methods led to the same result—namely, that the glass spaces out the more as compared with the less refrangible part of the spectrum no more than an ordinary glass of similar dispersive power. As in the phosphatic series, the titanium reveals its presence by a considerable increase of dispersive power; but, unlike what was observed in that series, it produces no sensible effect on the irrationality. The hopes, therefore, that had been entertained of its utility in silicic glasses prepared for optical purposes appear doomed to disappointment.

P.S.—Mr. Augustus Vernon Harcourt has now completed an analytical determination which he kindly undertook of the titanic acid. From 2·171 grammes of the glass he obtained ·13 gramme of pure titanic acid, which is as nearly as possible 6 per cent.

On the Effects of Heat on the Molecular Structure of Steel Wires and Rods.

By Professor W. F. Barrett.

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* Report for 1874, Transactions of the Sections, p. 26.

Experiments on Magnetized Rings, Plates, and Disks of Hardened Steel. *By* P. BRAHAM.

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*On the Decomposition of an Electrolyte by Magneto-Electric Induction**. *By* J. A. FLEMING, *B.Sc.* (*Lond.*), *F.C.S.*

When a solid conductor is moved on a magnetic field induced currents are created in it. In a solid these expend themselves partly or wholly in producing heat in the conductor. This paper is occupied with an examination of the effect produced on electrolytes under the same circumstances, viz. when made to flow or move in a magnetic field. Experiments are described to show, first, that induced currents are produced under these conditions in electrolytes, and then that the electrolyte is to some slight extent decomposed by these currents.

The experiment which gives grounds for making this statement may briefly be described thus:—A glass tube, 2 centims. in diameter, has platinum plates placed in its interior at the sides; these are welded to platinum wires sealed through the glass. The tube is supported between the poles of a powerful electromagnet in such a way that the tube is perpendicular, and the line joining the plates is at right angles to the line joining the poles. This tube is connected, by means of a siphon, with a reservoir of dilute sulphuric acid, placed at a height of about 3 metres above the floor. After filling the tube and siphon and carefully depolarizing the plates, the magnet is magnetized by a current from twenty Grove's cells, and then the plates connected by wires with a delicate mirror-galvanometer in another room.

On allowing the liquid to flow down, the galvanometer indicates a current passing across from one platinum plate to another; this is the induced current created by the flow of the liquid in the magnetic field. Various and numerous precautions have to be taken to prevent any movement or vibration of the platinum plates and variation in the strength of the field. The magnet being kept magnetized, the plates are then short-circuited, after having been carefully depolarized, and the liquid allowed to flow down. When the acid is nearly exhausted, this short circuit is broken and the flow of the liquid immediately after stopped. On joining the plates to the galvanometer a *reverse* current is now perceived—that is, one opposite in direction to the real induced current. This indicates that the plates have become polarized again by the effect of the induced current created by the flow of the electrolyte in the magnetic field. It was found that this polarization could be rendered more decided by covering over the platinum plates with a layer of coarse cloth, or by placing a cloth tube in the interior of the glass one in such a way that the liquid flows down the *inside* of this tube, but the platinum plates are on the *outside*. The reason of this is because the rapid downrush of the liquid mechanically clears away the film of gases from the plates, and so renders the polarization less than it should be.

In the last part of the paper the question is raised of how far the foregoing facts may have interfered with the success of Faraday's experiment on the flow of the Thames at Waterloo Bridge. Since this polarization introduces a reverse electromotive force, unless the electromotive force due to the strength of field and velocity and width of stream is greater than that required to decompose water, no *permanent* current can be produced in an electrolyte flowing in a magnetic field, but only a transient one, the strength of the induced current rapidly decreasing as it polarizes the electrodes.

On the Position of the Magnetic Equator in the Gulf of Siam and in the Gulf of Bengal. By Dr. J. JANSSEN.

Dr. Janssen made observations at Bangkok, Bangchallô, Ligor, Singora, and Singapore; and he concludes that the magnetic equator passes between Ligor and Singora about 7° 43′ north latitude.

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* Published *in extenso* in the 'Electrical News,' September 2, 1875.

The line without declination passes very near Singapore.

In the Gulf of Bengal the equator passes through the north of Ceylon (the exact position will be given).

The position of Ligor has been corrected. It is erroneously placed on the maps, latitude 8° 24′ 30″.

On the Magnetizing Function of Iron, Nickel, and Cobalt.
By H. A. Rowland.

On Magnetic Distribution. *By* H. A. Rowland.

On the Effect of Stress on the Magnetism of Soft Iron.
By Sir W. Thomson, *F.R.S., F.R.S.E.*

Meteorology.

On the Influence of the Physical Properties of Water on Climate. *By* Henry Hennessy, *F.R.S., Professor of Applied Mathematics in the Royal College of Science for Ireland.*

The conditions of climate depend essentially on the thermal properties of the materials of the earth's outer coating. These materials are solid, liquid, and gaseous; and inaccurate ideas as to the relative thermal influence of these several substances necessarily lead to erroneous conclusions regarding problems of climate affecting both the present meteorology of the globe and its past geological history.

Several years since Sir John Herschel enunciated his views on this question very clearly in the following words:—"The effect of land under sunshine is to throw heat into the general atmosphere and to distribute it by the carrying-power of the air over the whole earth.

"Water is much less effective in this respect, the heat penetrating its depths and being there absorbed, so that the surface never acquires a very elevated temperature, even under the equator"*. These views, owing to the high name of their author, have naturally commanded much attention, and have been quoted in support of theories of terrestrial climate. This has been done especially by the late Sir Charles Lyell, in all the recent editions of his celebrated 'Principles of Geology.' As Sir John Herschel's views may still exercise an important indirect influence over inquiries into terrestrial climate, the author called attention to the entirely different conclusions presented by him some time before the publication of the edition of Sir John Herschel's work from which the foregoing passage is quoted.

On carefully considering the properties of land, air, and water, with reference to heat (namely, their specific heat or capacity for heat, their properties with reference to conduction and convection, radiation and diathermancy), he came to the conclusion that of all substances largely existing in nature, water was that most favourable to the absorption and distribution of solar heat throughout the external coating of the earth.

The relative heat-storing power of substances depends upon their specific heat; and thus the results published by Pfaundler in Poggendorff's 'Annalen' for October 1866, p. 102, have an immediate bearing on our inquiries. He has found that the specific heat of soils varies from 0·50 down to 0·19, taking the specific heat of water as unit. The lowest specific heat is found in sandy soils free from vegetable earth or humus. We may in general assume that dry sand, whether calcareous or siliceous, has only one fifth of the specific heat of water. As we might expect, this inquirer has found that small capacities for heat are favourable to great fluctuations of soil-temperature, while large capacities have the effect of lessening such fluctuations. A sandy soil, such as that of the great African desert, although capable of exhibiting a very high temperature during the day, becomes cooled down during the night, and is one of the worst substances for storing up the heat derived from sunshine. Water, on the contrary, stores up such heat better than almost any other body.

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* Outlines of Astronomy, 1864, p. 236.

The grounds for the author's conclusions as to the thermal properties of water were fully exhibited in a paper published in the 'Atlantis' and the 'Philosophical Magazine' for 1859, and subsequently republished wholly or partially in some foreign scientific journals. Instead of the dictum expressed by Sir John Herschel, we may make the following almost diametrically opposite announcement. The effect of land receiving sunshine is to throw off the heat it receives, not only into the atmosphere, but into the interplanetary spaces by night as well as by day; and thus, although it rapidly produces a considerable increase of temperature in the stratum of air immediately in contact with it during the day, it is ill adapted for storing up and retaining the thermal energy it has received. Water is much more effective in this respect; heat penetrates to a greater depth within it, and afterwards becomes more steadily absorbed, owing to the much higher specific heat of water and the ratchet-wheel action exercised on the luminous heat-rays from the sun, which, on their transformation into obscure rays, cannot again return through the liquid. Prof. Tyndall has established that this ratchet-wheel action of water exists for water in its vaporous state as well as in its ordinary condition, and accordingly that a vapour-charged atmosphere, though comparatively diathermanous for the sun's heat-rays, which pass without considerable loss to the earth's surface, yet this moist air almost completely stops the radiation of non-luminous heat from the ground.

In his earlier researches the author pointed out how the distribution of heat over the Caribbean Sea and the Gulf of Mexico, and the general laws followed in the distribution of the isothermal lines of islands, and especially in the British Isles, confirmed these views.

At this Meeting a remarkable confirmation is afforded by the results communicated by Captain Toynbee, whereby he has shown that in the equatorial Atlantic the water-surface temperature is higher than the air-temperature above it. With regard to geological climate, these conclusions were long since adopted and acknowledged by Professor Phillips. They have been also adopted, but not acknowledged, by other writers besides the distinguished and lamented geologist to whom this Association is so greatly indebted.

The distribution of terrestrial temperature depends essentially both on oceanic and atmospheric currents, and the question of oceanic circulation is thus closely connected with that of climate. Much attention has been recently excited by two theories—one which ascribes oceanic currents to the motions of the atmosphere, and the other to the direct influence of gravity on masses of water unequally heated. This or the gravitation-theory has been already broached in the author's paper already referred to. It has been recently pursued in more detail, and with his usual ability, by Dr. Carpenter.

On the possible Influence on Climate of the substitution of Water for Land in Central and Northern Africa. By Prof. H. Hennessy, *F.R.S.*

The author referred to the fact that more than six years since he had put forward proofs of the connexion between some of the hot winds which blow from the south-west in Central and Southern Europe with the currents of the Atlantic and not with the desert of Sahara, as has been usually supposed*. Similar views had been also enunciated by Prof. Wild, Director of the Physical Observatory of Russia, Prof. Dufour of Lausanne, Dr. Hann, and other meteorologists. The attention excited by the great midday heat of Central Africa caused many to overlook the remarkably low nocturnal temperature, and thus to ascribe to the desert a thermal influence which it does not possess. The conclusions which the author has established with regard to the physical properties of water in connexion with climate (of which

* Proceedings of the Royal Irish Academy, vol. x. p. 496.

a *résumé* is presented in the preceding paper) enable us to infer that the substitution of an area of water over the Sahara for the existing dry land would be followed by the storing up of the heat received so largely in that region from the sun's rays which is now partly dissipated by nocturnal radiation.

A great Mediterranean sea in Africa, possessing an area equal to the Gulf of Mexico and Caribbean Sea, would become, like these seas, a source of positive thermal influence on distant places. In the Red Sea the temperature is high by night as well as by day, and this would also occur in the hypothetical Mediterranean of the Sahara. The evaporation from its surface would give to the air above an immense mass of vapour containing heat in a potential or latent state. This vapour-charged atmosphere, like a similar atmosphere over the Atlantic, would tend, in consequence of the earth's rotation, to move from south-west towards north-east, thus carrying heat towards the western regions of Asia and the eastern part of Europe. The climatal effect of this sea would, upon the whole, result in a higher mean temperature for these parts of the globe, and it would undoubtedly not operate in producing a lower temperature in Europe so as to cause a descent of the snow-line. Its action, if any, would probably be the reverse.

On the apparent Connexion between Sun-spots, Atmospheric Ozone, Rain, and Force of Wind. By J. MOFFAT, *M.D., F.G.S., &c.*

In this paper the author stated that, in discussing ozone observations from 1850–69, he observed that the maximum and minimum of atmospheric ozone occurred in cycles of years, and that he had compared the number of new groups of sun-spots in each year of these cycles with the quantity of ozone; and the results showed that in each cycle of maximum of ozone there is an increase in the number of new groups of sun-spots, and in each cycle of minimum of ozone there is a decrease in the number of new groups of sun-spots.

In a Table he also showed that there is an increase in the quantity of rain and the force of wind with the maximum quantity of ozone and sun-spots, and a decrease in these with the minimum of ozone and sun-spots.

On the Rainfall in Monmouthshire and the Severn Valley on July 14th, and on some subsequent Floods in England and Wales. By G. J. SYMONS.

The author stated that it would hardly have been right to say nothing about the wonderful rainfall in the neighbourhood of Bristol on the day named. The rainfall was simply a mass of vapour that came up from the west, and commenced to fall as rain at Tenby between midnight and 1 A.M. on the morning of the 14th of July. Its front edge travelled at the rate of about 18 miles an hour; and at 4 P.M. on the same day it passed off by the north coast of Norfolk. As to its breadth, it took about 36 hours to pass over any given point. The quantity of water that fell varied very much over the whole country, and was deepest on the west side of a line drawn from the Isle of Wight to the Isle of Sheppey, and thence to the north-west. Most stations in Monmouthshire and Glamorganshire had a rainfall of over 3 inches; at fourteen stations the rainfall exceeded 4 inches, at six it was over 5 inches; and at Tintern Abbey, usually considered a dry station, the rainfall was 5·31 inches in 24 hours. The result of this heavy rain was, as many of the inhabitants of Bristol knew too well, that most of the low-lying parts had been flooded. This was followed, especially in the Midland Counties, and as far north as Manchester, by storms in which from 2 to 3 inches of rain fell; and this coming on saturated ground, a great deal of damage was done in Leicestershire, Cambridge, and Huntingdon; and he mentioned as an instance that when the day arrived for holding the Huntingdon races, the race-course was 2 feet 6 inches under water. The rainfall during July was wonderfully concentrated; for instance, at Tamworth there was the extraordinary fall of 9¼ inches in 8 days, or ⅓ of the average rainfall for a year.

CHEMISTRY.

Address by A. G. Vernon Harcourt, *M.A., F.R.S., F.C.S., President of the Section.*

To the privilege of presiding over this Section custom has added the duty of offering some preliminary remarks upon the branch of science for whose advancement we are met.

In discharge of this duty some of my predecessors have reviewed the progress of Chemistry during the previous year; and until a few years ago there was no more needful service that your President could render, though the task of selection and abstraction was one of ever-increasing difficulty. But a few years ago the wisdom and energy of Dr. Williamson transformed the Journal of the Chemical Society into a complete record of chemical research, and this Association materially promoted the advancement of science when it helped the Chemical Society in an undertaking which seemed at one time hopelessly beyond its means. The excellent abstracts contributed to the Journal err, if at all, on the side of brevity; and yet the yearly volume seems to defy the bookbinder's press. I shall not venture to attempt further abstraction, nor to put before you in any way so vast and miscellaneous an aggregate of facts as the yearly increment of chemistry has become. The advancement of our science (to borrow again the well-chosen language of the founders of this Association) is of two kinds. The first consists in the discovery and co-ordination of new facts; the second in the diffusion of existing knowledge and the creation of an interest in the objects and methods and results of scientific research. For the advance of science is not to be measured only by the annual growth of a scientific library, but by the living interest it excites and the number and ardour of its votaries. The remarks I have to offer you relate to the advancement of Chemistry in both aspects.

One fact has been brought into unpleasant prominence by the Journal of the Chemical Society in its present form—namely, the small proportion of original work in Chemistry which is done in Great Britain. All who are ambitious that our country should bear a prominent part in contributing to the common stock of knowledge, and all who know the effect upon individual character and happiness of the habit and occupation of scientific inquiry, must regret our backwardness in this respect. The immediate cause is easily found. It is not that English workers are less inventive or industrious than their fellows across the Channel, but that their number is exceedingly small. How comes it that, in a country which abounds in rich and leisurely men and women (for neither the reason of the case, nor the jealousy of the dominant sex, nor partial legislation excludes women from sharing this pursuit with men), there are so few who seek the excitement and delights of chemical inquiry? Moralists tell us that the reason why some men are content with the pleasures of eating and drinking and the like is, that they have never had experience of the greater pleasure which the exercise of the intelligence affords. I am not about to represent it as the moral duty of those who have means and leisure to cultivate Chemistry or any branch of science; but no taste for a pursuit can be developed in the absence of any knowledge of its nature. A taste for Chemistry is often spoken of as a peculiar bias with which certain men are born. No doubt there are differences in natural aptitudes and tastes; but the chief reason why it is so rare for men of leisure to addict themselves to scientific pursuits is, that so few boys and young men have had experience of the pleasure which they bring. Much has been done during the last twenty years, both at the Universities and at the Public Schools, to provide for the teaching of science. To speak of what I know best, the University of Oxford has made liberal provision for the teaching of science, and for its recognition among the studies requisite for a degree; nor have the several Colleges been backward in allotting Scholarships and Fellowships as soon as and whenever they had reason to believe that those elected for proficiency in science would be men equal in intellectual calibre to those elected for proficiency in classics or mathematics. But the result is somewhat disappointing; and under a free-trade system science has failed to attract more than a small percentage of University students. Excellent lectures are delivered by the Professors to scanty audiences, and the great bulk of those educated at the University receive no more tincture of science than their predecessors did twenty years ago.

The recognition of Science among the subjects of University examinations is by no means an unmixed advantage to those concerned. Examinations have played and will continue to play a useful part in directing and stimulating study, and in securing the distribution of rewards according to merit; but they produce in the student, as has often been pointed out, a habit of looking to success in examination as the end of his studies. This habit of mind is peculiarly alien to the true spirit of scientific work. Only such knowledge is valued as is likely to be producible at the appointed time. Whether a theory is consistent or true is immaterial, provided it is *probable*—that is to say, advanced by some author whose authority an examiner would recognize. All incidental observations and experimental inquiry lying outside the regular laboratory course, which are the natural beginnings of original work, must be eschewed as trespassing on the time needed for preparation. The examination comes; the University career is at an end; and the student departs, perhaps with a considerable knowledge of scientific facts and theories, but without having experienced the pleasure, still so easily gained in our young science of Chemistry, of adding one new fact to the pile of knowledge, and, it may be, with little more inclination to engage in such pursuit than have most of his contemporaries to continue the study of Aristotle or Livy.

However, examinations have their strong side, to which I have referred, as well as their weak side; and although it is the natural desire of a teacher to see his more promising pupils contributing to the science with whose principles and methods they have laboured to become acquainted, the younger, like the elder, branches of knowledge must be content to serve as instruments for developing men's minds. Chemistry can only claim a place in general education if its study serves, not to make men chemists, but to help in making them intelligent and well informed. If it is found to serve this purpose well, the number of chemical students at the Universities ought to increase; and if the number increases, no rigour of the Examination System will prevent one or two, perhaps, in every year adopting Chemistry as the pursuit of their lives. But the Universities have little power to determine what number of students shall follow any particular line of study. With certain reserves in favour of classics and mathematics, their system is that of free trade. Young men of eighteen or nineteen have tastes already formed, some for the studies which were put before them at school (in which, perhaps, they are already proficient and have been already successful), some for games and good-fellowship. It is, from the nature of the case, with the masters of schools that the responsibility rests of fixing the position of science in education. During the last ten years provision has been made at most of the larger schools for the teaching of some branches of science; and those who recall the conservatism of schoolboys, and their consequent prejudice in favour of the older studies, will understand a part of the difficulties which have had to be encountered. The main and insurmountable difficulty is what I may call the impenetrability of studies. A new subject cannot be brought in without displacing in part those to which the school-hours have been allotted. It is the same difficulty which occurs again and again in human life. There are many things which it would be well to know and well to follow; but life, like schooltime, is too short for all. From the educational phase of this difficulty the natural difference of tastes and aptitudes provides in some degree a way of escape. I think that wherever a school can afford appliances for the teaching of Chemistry, all the boys should pass through the hands of the teacher of this subject. Two or three hours a week during one school-year would be sufficient to enable the teacher to judge what pupils were most promising. There may be instances to the contrary; but I do not think it likely that any boy who attended chemical lectures for a year without becoming interested in the subject would ever pursue it afterwards with success. Suppose that out of one hundred boys who have gone through this course five are selected as having shown more intelligence or interest than the rest; they should be permitted to give a considerable part of their time, while still at school, to studying science, without suffering loss of position in the school or forfeiting the chance of scholarships or prizes. If any such system is possible and were generally adopted, each school sending annually to the Universities, or other institutions for the education of young men, its small contribution of scientific students, the Professors' lecture-rooms and laboratories would be filled with young men who had already learnt the rudiments of science. Laboratories of research as well as of elementary instruction would find a place at the English Universities, and the reproach of barrenness would be rolled away.

Some of the defects or difficulties to which I have adverted are perhaps peculiar to our older schools and universities. The introduction of the study of natural science has borne earlier fruit in schools whose celebrity is of more recent date, such as the excellent College in this neighbourhood. Oxford and Cambridge ought to possess, but are far from possessing, such laboratories as have lately been built at the Owens College, Manchester. It is proposed to constitute in this city a College of Science and Literature, similar to Owens College and in connexion with two of the Oxford Colleges. The scheme set forth by its promoters appears thoroughly wise and well considered, and all who are interested in scientific education must wish it success.

I have placed first among the modes in which science, and in particular Chemical science, may be advanced the assignment to it of a more prominent and honoured place in education; but owing, as I do, my own scientific calling and opportunities of work to a bequest made to Christ Church by Dr. Matthew Lee more than a hundred years ago, I cannot forget or disbelieve in the influence of endowments.

I have spoken of the leisurely class in this country as that to which scientific Chemistry must look for its votaries. In our social conditions and in the absence of endowments it is hard to see where else they can be found. Men who have their livelihood to make cannot afford to spend money, and still less to bestow their time and energy, on the luxury of scientific inquiry. Even if they have the opportunity of earning their livelihood by scientific teaching, and with it the command of laboratory and apparatus, no leisure may remain to them for original work; and the impulse to such work (often, it must be admitted, of a feeble constitution) may be starved in the midst of plenty. The application of endowments to the promotion of original research is a difficult question. I am inclined to think that posts, constituted chiefly with this object, should be attached in every case to some educational body, and should have light educational duties assigned to them. The multiplication of such posts in connexion with the many colleges and schools in this country, where there is some small demand for chemical teaching, with the provision in each case of a sufficient laboratory and means of work, would probably do more than any centralized scheme for the promotion of chemical research.

To the advancement of Chemistry by the formation of public opinion on the questions of scientific education and the endowment of original research, the Chemical Section of the British Association may reasonably hope to contribute. But doubts have been expressed as to the serviceableness of this or any such organization for the direct advancement of our Science itself. No doubt we cannot accomplish much. Chemical inquirers at the present time may be compared to a party of children picking wild flowers in a large field; at first all were near together, but as they advanced they separated, till now they are widely scattered, singly or in groups, each busy upon some little spot, while for every flower that is gathered ten thousand others remain untouched.

That the Science of Chemistry would advance more rapidly if it were possible to organize Chemists into working parties, having each a definite region to explore, cannot, I think, be doubted. Is such organization in any degree possible?

The experiments of which Bacon has left a record, though curious historically, have no scientific value. But in one respect his 'Physiological Remains' furnish an example which we might follow with profit. "Furthermore," he writes, "we propose *wishes* of such things as are hitherto only desired and not had, together with those things which border on them, for the exciting the industry of man's mind." I will quote further, as an example, a part of one of his "wishes," which has very recently been fulfilled. "Upon glass four things would be put in proof. The first, means to make the glass more crystalline. The second, to make it more strong for falls and for fire, though it come not to the degree to be malleable."

I do not know that the industry of M. de la Bastie's mind was excited by Bacon's mention of glass more strong for falls and for fire among things hitherto only desired and not had; but the conception of such an enumeration seems to me worthy of its author. Much fruitless and discouraging labour might be saved, a stimulus might be given to experimental inquiry, and chemical research might become more systematic and thus more productive, if Bacon's example were followed by the leaders of Chemistry at the present day.

The Council of the Pharmaceutical Conference, whose meeting has just preceded our own, has published a list of subjects for research which they commend to the attention of Chemists. Where one of these subjects has been undertaken by any Chemist his name is appended to it. Might not the representatives of Scientific Chemistry issue a similar list?

Perhaps two or three of the distinguished English Chemists who are members of this Association might be willing to serve on a Committee, which should put itself into communication with the leaders of Chemical inquiry abroad, and should make and obtain and publish suggestions of subjects for research. Such a list so got together would, I think, find a welcome place in all scientific journals, and would thus be widely known and easily accessible to every student.

That which chiefly makes the organization of Chemical inquiry desirable is the boundless extent of the field upon which we have entered. Not every fact, however laboriously attained and rigorously proved, is an important fact in Chemistry any more than in other branches of knowledge. Our aim is to discover the laws which govern the transformations of matter; and we are occupied in amassing a vast collection of receipts for the preparation of different substances, and facts as to their composition and properties, which may be of no more service to the generalizations of the science, whenever our Newton arises, than were, I conceive, the bulk of the stars to the conception of gravitation.

It may, however, be urged that the growth of Chemical theory keeps pace with the accumulation of chemical facts. It is so, if the elaboration of constitutional formulæ is leading us up to such a theory. But at present, however useful and ingenious this mode of summarizing chemical facts may be, it does not amount to a theory of Chemistry.

Two objections to regarding such formulæ as any thing more than a chemical short-hand, as it has been termed, seem worth recalling. The first is mentioned at the outset in most text-books in which these formulæ are employed, but sometimes, I venture to think, lost sight of afterwards. The arrangement of the atoms of a molecule in one plane is equally convenient in diagrams and improbable as a natural fact. But is not this arrangement used as though it were a natural fact when the possible number of isomeric bodies is inferred from the number of different groupings of the atoms which can be effected on a plane surface? The conceptions of plane Geometry are much simpler than those of solid Geometry (which is another recommendation of the present system of formulæ); but so far as I am able to follow the similar theories which have recently been propounded independently by MM. Le Bel and Van 't Hoff, the consideration of the possible isomerisms of *solid* molecules leads to new conclusions *. Wislicenus has found that paralactic acid undergoes the same transformations as ordinary lactic acid when heated and when oxydized. The two acids differ in their action on polarized light. His conclusion is that paralactic acid does not differ in its atomic structure from the lactic acid of fermentation, and that the kind of isomerism which exists between the two acids is not connected with the difference in the reciprocal arrangement of the atoms, but rather with a difference in the geometric structure of the molecule. To this difference he gives the name of "geometric isomerism" †. The authors named above agree in supposing that the action of substances in solution on polarized light results from an unsymmetrical arrangement of atoms and radicles in three dimensions around a nucleus-atom of carbon.

The second objection relates to the statical character of the account which "developed" formulæ give of the differences between different kinds of matter. The modern theory of heat supposes not only that the molecules which constitute any portion of matter are in constant rapid motion, but that the atoms which constitute each molecule are similarly moving to and fro. Such movement might be an oscillation about the position assigned to the several atoms in the constitutional formula of the molecule. Since, however, the modes of formation and decomposition of substances are the principal facts upon which their formulæ are based, it is to be considered whether these facts may not depend altogether upon the nature or average nature of the motion impressed upon the atoms—that is, upon dynamical and not upon statical differences.

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* Bull. de la Soc. Chim. de Paris, t. xxii. p. 337, and t. xxiii. p. 295.

† Ann. de Chim. et de Phys., 5e série, t. i. p. 122.

Many substances are known whose existence is contrary to the theory of valency and saturation, such as nitric oxide and carbonic oxide; others which transgress the theory of isomerism, such as chloride of dichlordibromethane ($C^2 Cl^2 Br^2, Cl^2$) and bromide of tetrachlorethane ($C^2 Cl^4, Br^2$), which should be identical, but are isomeric *: yet these theories are simply an expression of the statement that certain substances can exist or can differ, while others cannot. It is true that in the vast majority of cases the theoretical limitation seems to hold good. But just as the absence of any fossil remains of the connecting links between species is only significant if the geologic search has been sufficiently thorough, so it is with chemical theories depending upon the non-existence of certain classes of bodies. Indeed, in our case, where investigation is guided by theory, and, as a rule, only those things which are looked for are found, the limitation may be partly of our own making. A Chemist who should depart from the general course, and set himself to prepare substances whose existence is not indicated by theory, would perhaps obtain results of more than the usual interest.

Among chemical inquiries, if ever such a list as I have ventured to suggest should be drawn out, I hope that many would be included relating to the most familiar substances and the simplest cases of chemical change. The thorough study of a few reactions might perhaps bring in more knowledge of the laws of Chemistry than the preparation of many new substances.

I believe that if any Chemist not content with a process giving a good yield of some product examines minutely the nature of the reaction, observing its course as well as its final result, he will find much more for study than the chemical equation represents. He will probably also find that the reaction and its conditions are of a formidable complexity, and will be driven back towards the beginnings of Chemistry for cases sufficiently simple for profitable study.

In concluding my remarks, I desire briefly to refer to another branch of Chemical Science, to the advancement of which this Association seeks to contribute—I mean, applied or technical Chemistry. One of the principal differences between the papers read before this Section, as a class, and those which the Chemical Society receives, is the larger proportion in our list of papers on technical subjects. Whatever Chemists may hold, there can be no doubt that the estimation of our science by the outside world rests largely on the well-founded belief that Chemistry is useful. Indeed, though scientific Chemists are justly eager to vindicate the value of investigations remote from any application to the arts, they cannot but feel a livelier sense of triumph when the successful synthesis of a vegetable principle yields at the same time a product of great technical value, as in the case of the production of artificial alizarin.

By visiting in turn the principal centres of British industry, this Association brings together men engaged on pure and on applied Chemistry. We who come as visitors may hope that our papers and discussions here may bring fresh interest in the science, if not actual hints for practice, to those whose art or manufacture is based on Chemistry. In return, the most interesting communications the Section has received have not unfrequently been the descriptions of local industries; and there is no part of our hospitable reception more welcome and more instructive to us than the opportunities which are provided of seeing chemical transformations on a large scale effected by processes which observation and inventiveness have gradually brought to perfection and with the surprising familiarity and skill which are engendered by daily use.

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* Bull. de la Soc. Chim. de Paris, t. xxiv. p. 114.

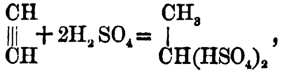
Note on a Method of effecting the Solution of difficultly Soluble Substances.
By A. H. ALLEN.

On the Nature of Berthelot's Vinylic Alcohol.
By HENRY E. ARMSTRONG, *Ph.D.*

According to Berthelot, acetylene is slowly absorbed when agitated with concentrated sulphuric acid; and if the solution be diluted with water and distilled, a liquid product is obtained which is slightly more volatile than water, and possesses an extremely pungent odour recalling somewhat that of acetone.

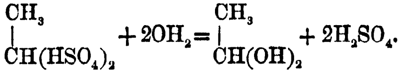
This product does not appear to have been obtained in a state of purity and analyzed; nevertheless Berthelot regards it as vinylic alcohol ($C_2H_3 . OH$), formed by the addition of the elements of a molecule of water to a molecule of acetylene; and it is described as such in several of our text-books. The author believes, however, that theoretical considerations warrant a totally different conclusion.

Thus experience entirely justifies the assumption that the first action probably consists in the combination of a molecule of acetylene with *two molecules* of sulphuric acid in the manner represented by the equation



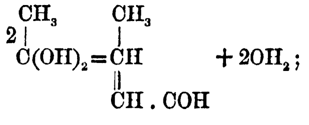
$$\begin{array}{c}CH\\ |||\\ CH\end{array} + 2H_2SO_4 = \begin{array}{c}CH_3\\ |\\ CH(HSO_4)_2\end{array},$$

and that the compound thus formed would be resolved by distillation with water into sulphuric acid and aldehyde-hydrate:



$$\begin{array}{c}CH_3\\ |\\ CH(HSO_4)_2\end{array} + 2OH_2 = \begin{array}{c}CH_3\\ |\\ CH(OH)_2\end{array} + 2H_2SO_4.$$

But Kekulé and Zincke's experiments on the condensation of aldehyde lead us to believe that the aldehyde thus produced would, under the influence of the sulphuric acid, be converted into *crotonic aldehyde*:



$$2\begin{array}{c}CH_3\\ |\\ C(OH)_2\end{array} = \begin{array}{c}CH_3\\ |\\ CH\\ \|\\ CH . COH\end{array} + 2OH_2;$$

and since the properties of Berthelot's product agree closely with those assigned to crotonic aldehyde, there can be little doubt that the supposed vinylic alcohol is in reality that compound, especially as the properties (b. p. &c.) of the "vinylic alcohol" are not at all those which are likely to characterize the lower homologue of allylic alcohol. Experiments to prove this are already in progress.

On the Alkaloids of the Aconites. By G. H. BECKETT *and* C. R. ALDER WRIGHT, *D.Sc., Lecturer on Chemistry in St. Mary's Hospital Medical School.*

Through the kindness of Mr. J. B. Groves, of Weymouth, we received for examination a quantity of the crystalline mixed nitrates of certain bases contained in *Aconitum napellus*, together with the hydrochloride of a base which separated from the liquor at a certain state of concentration during the process of extraction, and a crystalline base extracted from *A. ferox*; the method of extraction was, in each instance, essentially exhaustion by alcoholic hydrochloric acid, evaporation to a small bulk, and extraction of the alkaloids by addition of ammonia and ether.

After careful purification, the hydrochloride above mentioned gave numbers which are best represented by the formula $C_{31}H_{45}NO_{10}$, HCl, $1\frac{1}{2}H_2O$. This salt crystallizes from water in small silky crystals, but the solutions have a strong tendency to supersaturation: the free base refuses to crystallize from ether or alcohol, separating as a varnish which becomes a mass of crystals on moistening with a drop of dilute hydrochloric or nitric acid; this base appears to be almost inert, its salts possessing a bitter taste, not producing the prickling of the tongue characteristic of the aconites, and, according to Mr. Groves's observations, producing no result when swallowed by the human subject in half-grain doses.

From the mixture of nitrates a base was extracted (by means of spontaneous evaporation of the ethereal solution of the mixed free bases) which crystallized readily from ether in small anhydrous crystals, producing energetically the aconite tongue-prickling, and forming well-crystallized salts; the yield of pure base from 2 cwt. of roots was, however, very small, being only a very few grains. This substance gave numbers agreeing with the formula $C_{33}H_{45}NO_{11}$, the air-dry hydrochloride containing $3H_2O$; the body answered to the description of crystalline "aconitine" given by Duquesnel; but the formula arrived at by this chemist was $C_{27}H_{40}NO_{10}$.

The base from *A. ferox* gave numbers agreeing with the formula $C_{36}H_{49}NO_{11}$; it crystallizes in indistinct crystals from ether and alcohol by spontaneous evaporation: its salts refuse to crystallize, drying up to varnishes. On leaving the freshly precipitated free base in contact with water and emulsin a change is produced, a salt of an alkaloid not yet investigated being gradually formed in solution; no glucose, however, can be detected in the liquid.

Apparently the two last described bases of the aconites are readily alterable; on treating with mercuric iodide dissolved in potassium iodide the solution of their salts, iodo-mercurates, are precipitated; and on decomposing these with sulphuretted hydrogen, removing iodine by lead acetate and regenerating the bases by ammonia and ether, substances were in each case obtained possessing apparently a lower molecular weight than the original base used (*i. e.* the gold salt contained a somewhat larger percentage of gold). One specimen of the *A. ferox* base thus regenerated from the iodo-mercurate by Mr. Groves was magnificently crystalline, forming well-defined rhombohedra; whilst that examined by the authors (prepared by Mr. Groves from a different batch of roots) was only indistinctly crystalline, and quite different in appearance under the microscope. These and other analogous circumstances observed lead us to conjecture that either the constituents of the roots are variable under different conditions of soil, climate, &c., or that the alkaloids originally present are apt to undergo considerable changes during the process of extraction.

On Japanese Camphor from Peppermint. By G. H. BECKETT *and* C. R. ALDER WRIGHT, *D.Sc., Lecturer on Chemistry in St. Mary's Hospital Medical School.*

Oppenheim has shown that this camphor is a monatomic alcohol indicated by the formula $C_{10}H_{19}.OH$, and that by the action of dehydrating agents it loses the elements of water, forming a hydrocarbon, menthene, $C_{10}H_{18}$.

Through the kindness of Mr. John Moss (Messrs. Corbyn and Co.) we received a quantity of this camphor, and obtained the following corrected values for the melting- and boiling-points of the purified substance and its derivative menthene:—

Camphor,	melting-point	42° (in capillary tube).
„	boiling-point	212°.
Menthene,	„	164°·5 to 165°·5.

Mr. Moss found 39° as the melting-point and 37° 5 as the solidifying point of another specimen of camphor less completely purified; whilst Oppenheim gives 36° as the melting-point and 210° as the boiling-point of the camphor, and 163° as the boiling-point of menthene.

On cautiously adding four equivalents of bromine to menthene combination takes place, energetically at first, more slowly ultimately. The final product, $C_{10}H_{18}Br_4$, may be regarded as a derivative of a marsh-gas homologue, $C_{10}H_{22}$, *i. e.* as *tetra-bromo-decane*; on heating, this substance breaks up into *cymene* and hydrobromic acid, thus:—

$$C_{10}H_{18}Br_4 = 4HBr + C_{10}H_{14}.$$

The cymene thus obt ed is identical with that described in former Reports t Association by one of being produced from numerous terpenes and subst contained in essentia nd allied to the terpene family.

It thus results tha single reaction of decomposition a paraffine substi derivative breaks up, ng a benzene homologue, a somewhat unusual quite novel reaction.

Simultaneously wi d Japanese peppermint-camphor a liquid oil is imp this seems to be the liquid portion of an essential oil from which the solid h partially separated by standing and pressure. From the results obtained, it that this oil consists either of the solid camphor or of a liquid isomeride diss or mixed with a liquid oil of composition $C_{10}H_{18}O$, and identical or isome the similar substance constituting the majority of citronella-oil. By the dehydrating agents, menthene, terpenes and their polymerides, and resino are formed from the liquid oil.

Some further Experiments on Crystallization of Metals by Elect

By P. Braham.

Some Account of the Manufacture and Refining of Sugar in Bristo

By Henry T. Chamberlain.

For about two centuries refining of sugar has been carried on here style was rude and little beyond melting in open pans by fire heat, an the sugar to granulate. This old and uncertain process was much short new style and improvements, which consisted of the use of animal c the vacuum-pan, afterwards followed by the introduction of the centrifug for all sugar except loaf.

There is now scarcely any loaf made in England; the French have an ally unfair monopoly. The refiners now make only finest crystals, fin pieces, and treacle, most of them pleasing to the eye and pure in quality knowledge is now brought much into use in sugar-refining. The foll of manufacture is used by most refiners. The raw sugar as imported i a little water, then filtered through bags, and afterwards through a into cisterns, the first runnings pure and colourless as water; it is t *vacuo*, at a low temperature, to the granulating point, taken from t centrifugal machine, where in a few minutes of revolution all moist driven off, and the sugar remains finished and fit for use. As far as possible, all syrups are allowed to run by gravitation to save pumping. All syrups uncrystallizable form treacle, all washings and sweet water are evaporated, and not a particle of saccharine matter is lost.

There are four sugar-refineries in Bristol, working, or capable of working, 1700 to 1800 tons weekly.

Action of Ethyl-bromobutyrate upon Ethyl-sodaceto-acetate.

By F. Clowes, *B.Sc., F.C.S.*

Ethyl-bromobutyrate was prepared by the method of Gorup-Besanez and Klinksieck*, and the fraction boiling between 175° and 185° C. was added slowly to a benzene solution of ethyl-sodaceto-acetate prepared as directed by Wislicenus †. A violent reaction occurred with evolution of much heat and separation of sodium bromide.

After heating the mixture on the water-bath until no further separation of sodium bromide occurred, the benzene was removed by distillation, and the sodium bromide by washing with water. The resulting liquid was rapidly fractionated, and the portion which distilled over between 260° and 263° again fractionated; on being subjected to an elementary analysis it yielded the following analytical numbers, which agree perfectly with those required by diethyl aceto-ethyl succinate:—

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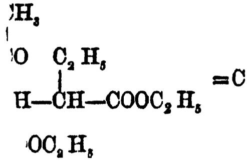
* Ann. Chem. u. Pharm. cxviii. 248.

† Ber. Ber. vii. 685.

0·2044 grm. of substance yielded 0·1517 H_2O and 5 CO_2.
0·2039 grm. of substance yielded 0·1504 H_2O an(12 CO_2.



$$=C_{12}H_{20}O_5=$$

	Theory.	Found. I.	Found. II.
C=	59·02	59·04	59·01
H=	8·19	8·24	8·19
O=	32·79	32·72	32·80
	100·00	100·00	100·00

ıew ether is a colourless liquid of peculiar unpleasant smell; its boiling-about 262° C.; as indicated by theory, it acts readily upon sodium with of hydrogen.

rther study of the properties of this ether and of its isomer derived from acid, and more especially their decomposition under the influence of vdrates, are already under investigation.

The Tobacco Trade of Bristol. *By* Thomas Davey.

'e Method of determining the Proportion of Carbonic Acid in Air.
By A. S. Davis.

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the Chemical Theory of Gunpowder. *By* Dr. Debus, *F.R.S.*

ır stated that ever since the introduction of gunpowder this subject has ısiderable attention from chemists. The French chemist Gay-Lussac ıt to make a systematic analysis of the products of combustion; but it sible satisfactorily to explain the reactions taking place by a formula. es of Professor Bunsen and Schischkoff have shown that a much larger ›ducts is formed than was previously supposed, rendering it even more ɪplain the nature of the changes taking place by a symbolic formula. ısen, of Heidelberg, found, by the combustion of a mixture of hydrogen and ca. oxide with a quantity of oxygen not sufficient to burn the whole of the two gases, that the water and carbonic acid produced stood to each other in proportion of their molecular weights, or their molecular weights multiplied by simple coefficients; and these coefficients may be the same for mixtures of various compositions, but change suddenly when the amount of one or both of the gases is changed beyond certain limits. The author has shown that the same law obtains when a mixture of baric and calcic chloride is precipitated by an insufficient amount of sodic carbonate, viz. that the barium carbonate and calcium carbonate precipitated are in proportion of their molecular weights, or their molecular weights multiplied by a simple coefficient. A necessary condition is that the reactions should be simultaneous. In the combustion of powder in an ordinary gun this condition is very nearly satisfied, and accordingly the quantities of some of the products formed obey the law enunciated by Bunsen. The author deduced from the analytical results published in Messrs. Noble and Abel's most excellent researches on fired gunpowder, as well as from the analyses of the products of the combustion of powder published by Bunsen and Schischkoff, the following general results concerning the products of combustion:—(1) the sum of the potassium contained in the potassic hyposulphite, sulphate, and sulphide stands to the potassium in the potassium carbonate approximately in simple proportions; (2) the carbon of the carbonic oxide stands to the carbon of the potassic carbonate also approximately in a simple proportion. From this, as well as from the relation of the sum of the potassium contained in the sulphide and hyposulphite to the potassium in the sulphate, it is possible to form a theory for the combustion of powder. There are several reactions between the constituents of powder when the latter is fired. Two of these are simultaneous; the way in which the others succeed each other cannot be accurately determined; at first, when a portion of the carbon is burned, potassic carbonate, carbonic oxide, nitrogen, and carbonic acid are produced. Simultaneously with this reaction, another takes place—a portion of the saltpetre and the whole or a portion of the sulphur form potassic sulphate and carbonic acid. The action of still unburnt carbon and of free sulphur on the potassic sulphate, in a succeeding stage of the combustion, causes the formation of potassic sulphide and hyposulphite. On the ground of such considerations, the processes taking place during the combustion of powder can be represented by equations. These, with other details, will be published elsewhere.

On the Manufacture of Sole-leather in Bristol.

By Sparke Evans, *Avonside Tannery.*

Very little notice is taken of the trade in city records, probably from the position of the tanneries being outside the city boundaries. In 1816 there were nine tanneries, now there are thirteen. The trade was formerly much fettered by absurd restrictions and excise laws. The leather made in this locality is of excellent quality, from proximity to oak-woods and the length of time allowed in tanning.

M'Cullock estimates the leather-trade as third in importance in the United Kingdom, giving precedence only to wool and iron.

The growth of commerce caused such a demand for leather that it would soon have attained a fabulous value but for the introduction of South-American hides and Turkish *Valonea*. South-American hides were first imported to Castile in 1580: total shipment from South America in 1872 of dry and salted hides 3,121,758, the produce of vast herds roaming over the pampas, which is estimated at 11 to 15 millions. Hides obtained of cattle in a semi-wild state much thicker than from high-bred animals. The loss occasioned by branding to prove ownership computed at £300,000 yearly.

The recent practice of pickling on the voyage strongly objected to, yet likely to prove its own cure.

Messrs. Conyers and Pullein have introduced a mode of suspending hides in lime, thus unhairing in four days without heat. Neither cool-sweating process used in America nor the sulphide of sodium or by charcoal used in Bristol.

Bristol early adopted the system of rounding. Failure of all patent processes for tanning. Rapid processes and new materials generally regarded with distrust, twelve months being required to make thick leather both pliable and impermeable. A considerable quantity of army leather supplied from this city, for which prize medals have been awarded. The British troops are better shod than any other soldiers in the world; and Sir Garnet Wolseley says, "The regiment that can march best in an army is the best in that army."

Increased working of large tanneries in favourably situated districts, and disappearance of small country yards. Five, for example, have been closed in Ashburton, Devon.

Kip tanning.—Imports estimated at 7,000,000. Average amount of plaster adulteration on each kip one and a half pound.

Principal tanning materials used in Bristol:—Oak-bark, *Valonea*, Myrobalan, *Mimosa*, Terra Japonica, Divi-Divi, and recently hemlock extract. *Valonea* having doubled itself in value, great need is felt for new materials, of which a few have been introduced, but not in commercial quantities.

Waste products.—Untanned portions of hide sold for sizing paper and manufacture of gelatine. Hair now largely used in manufacture of cheap clothing, blankets, and imitation of seal skins. Spent tan burnt for its ashes; lime-deposit useful as a manure.

Effect of Free Trade.—First American leather sent to England in 1844, quantity 1000 sides; in 1874, 1,159,854 sides, which pay no duty; while any English leather shipped to America must pay an import duty of more than 30 per cent.

Desirableness of importing live cattle from the River Plate, which may there be bought at £5 per head—thus importing meat, hide, bones, hair, and hoofs without waste.

Quantity of leather tanned in Bristol sufficient to provide soles for nine million pairs of boots annually. Various articles have been used as substitutes for leather, but very few have stood the test of time.

Great importance of preventing the tannic turning into gallic acid.—Unfortunately the trade generally are ignorant on chemical subjects, and will receive with much pleasure any information on the subject.

On the Separation of Lead, Silver, and Mercury, with a proposed process for estimation of Lead. By T. FAIRLEY, *F.R.S.E.*

These metals form a group generally precipitated together as chlorides, and various processes, more or less perfect, have been devised for their separation. Thus the silver chloride may be separated by ammonia, or the lead chloride by boiling with much water, or the mercurous chloride by boiling with nitric acid or aqua regia. This last is tedious and is open to the objection mentioned by Fresenius, that mercuric chloride volatilizes with the vapour from boiling water.

In the study of the reactions of hypochlorites and while engaged in teaching the ordinary course of analysis, the author ascertained that the conversion of mercurous chloride into soluble mercuric chloride is instantaneously effected by boiling with alkaline hypochlorite, taking care that the solution remains acid throughout.

The hypochlorite used may be potassium, sodium, or calcium hypochlorite. The author finds the most convenient to be a solution prepared by passing chlorine into a 10-per-cent. solution of sodium hydrate until the impurities (alumina &c.) contained in it begin to separate out. On then adding a small proportion of the sodium hydrate solution, say about one tenth of the quantity saturated with chlorine, we obtain a liquid of convenient strength, and which when kept in the dark remains almost unchanged.

Of course in the absence of acids &c. affecting the solubility of calcium compounds, solution of ordinary bleaching-powder may be used.

The separation of lead from mercurous salts may be readily performed by a continuation of the above process. If any free acid be present, add sodium acetate or hydrate and sufficient acetic acid to ensure an excess of the latter throughout the process. On boiling with hypochlorite all the lead is precipitated as brown dioxide. The dioxide so obtained is pure; and as no lead remains in solution the author has confidence that this may prove an accurate process for the estimation of lead.

On a new Method of preparing Periodates, with Application as a Test for Iodine and Sodium. By T. FAIRLEY, *F.R.S.E.*

When we boil any iodide or iodate with excess of alkaline hydrate and hypochorite, then, if sodium salts be present, a crystalline precipitate is after some time thrown down consisting of sodium periodate.

Using potassium hydrate and hypochlorite this test may be used to ascertain the presence of sodium compounds in any substance added to the boiling liquid. In a solution of about 30 cub. centims. in volume less than 0·1 gramme can readily be detected; and with a smaller volume more minute quantities may be detected.

As a test for iodine it is of course unable to take the place of more delicate well-known tests; but it is useful as affording in any case confirmatory evidence.

On new Solvents for Gold, Silver, Platinum, &c., with an Explanation of the so-called Catalytic Action of these Metals and their Salts on Hydrogen Dioxide. By T. FAIRLEY, *F.R.S.E.*

On the Use of Potassium Dichromate in Grove's and Bunsen's Batteries to ensure constancy. By T. FAIRLEY, *F.R.S.E.*

On Nitrite of Silver. *By* J. W. Gatehouse.

The Relation of the Arrangement of the Acids and Bases in a Mixture of Salts to the original manner of Combination. *By* Dr. J. H. Gladstone, *F.R.S.*

The question proposed for consideration was:—Suppose two salts (such as chloride of sodium and sulphate of magnesium) are mixed in equivalent proportions in a certain quantity of water, is the solution identical with a mixture of equivalent proportions of sulphate of sodium and chloride of magnesium in the same amount of water? The method employed for testing the question was to mix such pairs of solutions with a certain quantity of an intensely coloured salt, such as ferric sulphocyanide, ferric meconate, terbromide of gold, or platino-iodide of potassium, and to note the diminution of colour that resulted from the reciprocal decomposition of the constituents. Four separate pairs of mixtures were examined, and each pair proved identical in its action on the coloured salts. As small differences can be easily detected by such a method, the question may be considered as answered in the affirmative.

Notes on the Action of the Copper-Zinc Couple[*].
By Dr. J. H. Gladstone, *F.R.S.*, *and* Alfred Tribe.

Pure zinc will scarcely decompose a weak solution of sulphuric acid; but if a minute quantity of copper be deposited on the same zinc, it will decompose it readily.

Zinc which contains arsenic when "coupled" with copper decomposes pure water with the evolution of hydrogen which is free from arsenic. If, however, arsenious acid be added to the solution, arseniuretted hydrogen makes its appearance. The presence of this gas when arsenical zinc is dissolved in sulphuric acid is most probably due to the solubility of the arsenic in that acid.

On the Augmentation of the Chemical Activity of Aluminium by contact with a more Negative Metal[†]. *By* Dr. J. H. Gladstone, *F.R.S.*, *and* Alfred Tribe.

Aluminium alone decomposes water only at a white heat, but when "coupled" with copper or platinum it will decompose water slowly at the ordinary temperature and rapidly at 100° C. The aluminium-platinum couple, as might be expected, gives a still larger amount of hydrogen in the same time.

On an Apparatus for estimating Carbon Bisulphide in Coal-gas.
By A. Vernon Harcourt, *F.R.S.*

On Derivates of Mercaptan. *By* L. Jackson *and* A. Oppenheim.

On the Oxidation of the Essential Oils.—The Limited Oxidation of Terpenes and Cymene[‡]. *By* Charles T. Kingzett, *F.C.S. &c.*

This research is a continuation of work the results of which I have communicated to the Chemical Society (Journ. Chem. Soc. ser. 2, vol. xii. p. 511, & vol. xiii. p. 210).

In this Part the limited oxidation (by air) of terpenes of the general formula $C_{10}H_{16}$ and certain bodies related to terpenes, of the formula $C_{15}H_{24}$, and cymene ($C_{10}H_{14}$) is dealt with.

All terpenes represented by the expression $C_{10}H_{16}$ (so far as I have investigated) yield by atmospheric oxidation acetic acid and *peroxide of hydrogen*, and probably other bodies as yet undetermined.

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[*] Published *in extenso* in 'Phil. Mag.' October 1875.

[†] *Ibid.*

[‡] *Vide* 'Chemical News,' vol. xxxii. p. 138.

Thus *Hesperidene* (the terpene of oil of orange-peel) yielded an acid solution containing in 100 cub. centims. 0·154 gramme peroxide of hydrogen; and, moreover, a copper salt was prepared from an acid (not acetic) existing in solution which contained 12·85 per cent. copper. This acid is not precipitated from its combination with soda by acetic acid.

Myristicene.—With this terpene three experiments were made.

a. With ordinary oil of nutmeg. This yielded, when oxidized in the presence of water, an acid solution containing in one case 0·098 gramme peroxide of hydrogen in 100 cub. centims.

b. This experiment was made with the terpene isolated from nutmeg-oil by sodium treatment and fractional distillation. It boiled at 164° C., and consisted of terpene containing a little cymene. It yielded by oxidation a solution containing 0·0915 gramme peroxide of hydrogen in 100 cub. centims.

c. This third trial was made with that fraction of nutmeg-oil, hydrocarbons, boiling at 173°-175°, and therefore mainly cymene (as shown by Wright). This gave, on oxidation with water, a solution containing 0·0114 gramme H_2O_2 in 100 cub. centims.

Wormwood.—Wright (Journ. Chem. Soc. vol. xii. p. 317) has shown this oil to consist mainly of an oxidized body, $C_{10}H_{16}O$, containing some terpene.

It yielded peroxide of hydrogen on oxidation, although in small quantity.

Citronella contains, as Wright has shown, no terpene, but is mainly an oxidized body, $C_{10}H_{18}O$. It yielded, as was to be expected, *no* H_2O_2 on oxidation.

Ylang-Ylang.—This perfume (see a paper by H. Gil in 'Year-book of Pharmacy,' 1874) contains no terpene. It was subjected to atmospheric exposure in sunshine as a test, but developed *no* peroxide of hydrogen, showing it to contain no terpene, a result found by other means by H. Gil.

The oils of caraway, bergamotte, juniper, cubebs, lemon, and chamomile also absorb oxygen from air, forming in the presence of water peroxide of hydrogen. Their essential terpenes in a pure state have not yet been examined.

Such bodies of the formula $C_{15}H_{24}$ as I have examined fail to develop H_2O_2 by atmospheric oxidation.

This is true at least of the so-called clove terpene, isolated by Church from oil of cloves (Journ. of Chem. Soc. ser. 2, vol. xiii. p. 113), and also of patchouli, although it is to be remarked that the patchouli I examined was not oxidized by myself; and so the experiment requires repetition.

Cymene from all sources is identical, as proved by the researches of Fittica, Wright, and Paterno, &c. I have oxidized three samples:—

a. Cymene from camphor by zinc chloride. Of this 7 cub. centims. absorbed 52 cub. centims. oxygen in 18 days, and formed peroxide of hydrogen.

b. Cymene from the dibromide of cajeputol, boiling at 176°-177°, gave by oxidation with water a solution containing 0·196 gramme H_2O_2 in 100 cub. centims.

c. A mixture of quantities of cymene from various sources. This also gave affirmative results. Besides peroxide of hydrogen so obtained by atmospheric oxidation of cymene, a toluic acid seems also to be formed. A crystallized acid was obtained from the solution having the ordinary characters of a toluic acid; but there was not sufficient quantity to admit of analysis.

It is to be remarked that the oxidation in each case was effected by exposing the oils with water to sunshine and air, or passing a current of air through the mixture at 40° C.

I have shown, in Parts I. and II. of this research, that turpentine by oxidation in this way gives rise to the formation of *camphoric acid* and peroxide of hydrogen indirectly—that is, by the decomposition by water of a previously formed peroxide of an organic nature.

Bodies of $C_{20}H_{32}$ composition have not yet been examined.

These researches also prove that cymene is the nucleus matter of the terpenes; and thus is established another link between the terpenes and the benzene series.

Fittica (Deut. Chem. Ges. Ber. vii. 323) has shown cymene to be normal propyl-methyl-benzene in which the methyl and propyl occupy the paraposition.

Its atmospheric oxidation may possibly be expressed as follows:—

$$C_6H_4(CH_3)(C_3H_7)+O_6=C_6H_4(CH_3)CO(OH)+CH_3CO(OH)+H_2O_2,$$

thus obtaining by limited oxidation a toluic and acetic acid and peroxide of hydrogen.

When dilute nitric acid is employed as the oxidant toluic acid is formed; and in the case of stronger oxidants terephthalic acid is produced, the latter being a product *not* formed by atmospheric oxidation.

The production of peroxide of hydrogen from these bodies may possibly lead to a modification of the views of the constitution of hydrocarbons now entertained.

On the Treatment of Sewage. *By* J. C. MELLISS.

Some Remarks on Onynoitic Acid. *By* A. OPPENHEIM.

On Noctilucine. *By* DR. T. L. PHIPSON.

On Apparatus and Modes of Examination for the Source of Polluted Air.
By WILLIAM THOMSON, *F.C.S.*

This paper has reference principally to the detection and relative determination of the amount of hydrochloric and sulphuric acids issuing from chemical or other works surrounded by works which are also said to pollute the air, to prove the amount of pollution proceeding from any individual works.

My first experiments were confined to litmus-paper, which I found would not act well unless the papers were kept moist. To effect this I took bottles flattened on both sides, having a small hole bored in the shoulder; a piece of blotting-paper was fixed on the front of the bottle by elastic bands, and kept quite wet by a piece of cotton-wick passing through the small hole in the bottle, which was filled with pure water: the litmus-paper was then moistened with water and laid on the wet blotting-paper; it may thus be kept moist for any length of time without washing any of the litmus from the paper. If, then, several moist litmus-papers be kept at the side of the works, in a direct line with the direction of the smoke, and another set of papers placed at exactly the opposite side of the works, and both left for a few hours, a comparison of the two sets of papers will give a fair idea of the amount of acidity emitted by the works by the difference in point of redness of the litmus.

With the view to determine the actual amount of impurities put into the atmosphere by any individual works, I placed carbonic-acid bulbs, connected by means of india-rubber tubing with an aspirator, and so arranged them that by means of a pulley they could be raised or lowered through a range of about 30 feet on a jointed pole; by this means they could be placed as nearly as possible about the level at which the smoke and other vapours passed: but as the wind changed often it was necessary for the experiment that the pole, bulbs, and aspirators should be moved about in accordance with the changes in the direction of the wind; this was done by having the appliances fixed on a vehicle. About 120 gallons of air were passed through 500 grains of water alone and also made slightly alkaline with pure caustic soda, the apparatus being kept always in the direct line of the smoke from the works; and 120 gallons of air were passed through other bulbs, the apparatus always being kept to exactly the opposite side from that to which the smoke was blown. Thus I was enabled to get the relative amount of impurities in the atmosphere immediately before and immediately after it passed the works; and as it took about twelve hours to pass this quantity of air through each apparatus, it no doubt gave a fair estimate of the amount of impurities emitted by the works.

It is also advisable to corroborate these results by other means, such as collecting rain-water from different directions near the works, at the same time observing the direction of the wind during the time the rain is falling &c.

On a new Gaseous Compound of Fluorine and Phosphorus.
By Professor T. E. THORPE, *F.C.S.*

*Researches on the Crystalline Constituents of Aloes**.

By William A. Tilden, *D.Sc. Lond., F.C.S.*

Barbaloin is the name given to the aloin from Barbadoes aloes. It is a yellow, soluble, crystalline body, which yields substitution compounds with chlorine, bromine, and acetyl. Zanaloin (from Zanzibar aloes) is supposed to be identical with Socaloin (from Socotrine aloes), because the two compounds give the same qualitative reactions; but the latter has not been analyzed. Zanaloin, after drying in a vacuum, gives the same numbers as Barbaloin, the results of analysis in each case agreeing with the formula $C_{16}\,H_{18}\,O_7$. Zanaloin also yields substitution derivatives, the two series of isomeric compounds being expressed by the formulæ

$$C_{16}\,H_{15}\,Cl_3\,O_7,$$
$$C_{16}\,H_{15}\,Br_3\,O_7,$$
$$C_{16}\,H_{15}\,(C_2\,H_3\,O)_3\,O_7.$$

Zanaloin is distinguishable from Barbaloin by the action of strong nitric acid, which gives a crimson coloration with the latter; whilst with the former very slight change is manifest till heat is applied, when a bright orange-red colour is developed.

Note on Müntz and Ramspacher's Apparatus for the Estimation of Tannic Acid.

By John Watts, *D.Sc.*

The following arrangement was devised by MM. Muntz and Ramspacher in order to ascertain with accuracy the actual *leather-producing* power of an astringent substance, which, according to the experience of the manufacturer, does not appear always to coincide with its percentage of tannic acid.

The apparatus may be briefly described as a shallow gun-metal drum of about 200 cubic centims. capacity, permanently closed at one end by an india-rubber plate, and capable of being closed watertight at the other by a piece of depilated hide when clamped upon a stand over which the hide has been previously stretched. The drum is perforated at the side with a screw to admit of the introduction of the tanning liquor, and is fitted above with a screw-piston to compress the india-rubber disk. When the piston is lowered the liquor is forced through the hide, while the latter retains the whole of the tannic acid. The density of the liquor is taken before and after the operation by means of a very fine hydrometer graduated to a special scale, when the difference expresses at once the percentage value of the liquor operated on.

The advantages of the arrangement will be obvious to any one who has experience in analyses of this description; it is sufficient to say that the analysis is conducted with ease and rapidity, and that the average variation is about 0·5 per cent.

In order to compare the results of Ramspacher's tannometer with Hammer's table of percentages of tannin in solutions of different densities, and to compare both with the results of evaporation, a number of experiments were undertaken by the author, as shown below. The percentages only indicate the value of the particular sample under examination.

	By specific gravity.	By tannometer.	By evaporation.
Cube Gambier	41·45	40·44	47·43
Bale Gambier	42·44	39·50	49·02
Cutch	47·70	44·00	52·16
Valonea	25·32	25·32	26·30
Myrobalanes	32·30	30·28	31·08
Mimosa-bark	31·44	30·18	31·72
Blue Galls	60·00	59·10	——
Green Galls	53·40	52·41	57·90
Sumach	17·10	18·00	19·55
Divi-Divi	34·50	33·94	35·20

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* Published *in extenso* in the Pharm. J. Trans. (3) vi. 208.

The numbers in the first column were obtained by taking the specific gravity at 15° before and after removing the tannin, and obtaining the percentage equivalent from Hammer's Table. The third column was found by evaporating 25 cubic centims. in a platinum dish before and after the removal of the tannin, and drying the residue for three or four hours at 100°.

For further details the reader is referred to a memoir by Müntz and Ramspacher in the 'Ann. Chim. Phys.' 1875 [5], v.

GEOLOGY.

Address by Thomas Wright, *M.D., F.R.S.E., F.G.S., President of the Section.*

In taking this Chair today, I desire first to express my deep sense of gratitude to the Council of the British Association for the honour conferred on me, and, secondly, to say how much I feel the responsibility of the position in which I am placed when I recollect the long list of distinguished *savans* who in former years have presided over this Section. The fact that Buckland, Conybeare, De la Beche, Forbes, Geikie, Hopkins, Jukes, Lyell, Murchison, Phillips, Ramsay, and other men illustrious in the annals of British Geology have filled this chair, may well make me doubt how far my own feeble powers are equal to an efficient discharge of its duties; however, I shall bring a willing mind and an honest determination to do my best on this occasion.

We have met again in one of the most interesting centres in England to all students of practical geology; for within a short distance of this spot we can examine some of the most instructive sections of Palæozoic and Mesozoic rocks, and study a magnificent collection of local fossils obtained from them. So I purpose occupying the short space of time allowed for this introductory address in attempting to give you a general outline of the geological character of the country around Bristol, with a *résumé* of some of its more remarkable Palæontological features, by way of inducing you to visit and study the admirable collection of local organic remains so well displayed in the Museum of the Bristol Philosophical Institution.

Geology is the history of the Earth; for it attempts to construct a table of phenomena, physical and chemical, organic and inorganic, which have succeeded each other from the past to the present, and on the terrestrial surface traces of its origin and progress are preserved.

That phase which we see today is only the most recent of its eventful history, and although the last, is not the final one, as the physical forces that are ever in action among its different parts are slowly and steadily producing new combinations, which in time will effect mutations in its structure, change its physiography, and remodel the whole.

There is probably no other place in England where, within so limited an area, typical examples of so many different formations occur as around this city; for within a short distance by road or rail we may investigate the Silurian, Devonian, Carboniferous, Triassic, Liassic, Oolitic, and Cretaceous formations, all of which will yield many interesting species for the cabinet of the palæontologist, and a valuable series of rocks and minerals for the student of Physical Geology.

These different formations in relation to the entire series of stratified rocks will be better understood by a reference to the following Table, in which the periods, divisions, formations, and typical localities are given:—

Table I.—Geological Formations in the Bristol Districts.

Periods.	Divisions.	Formations.	Typical Localities.
Post Tertiary.	Recent	Alluvium	Bristol, Shirehampton.
		Peat	Cheddar, Glastonbury.
	Post Pliocene.	Gravel	Cheddar railway, Keynsham, Saltford.
Tertiary	......	....	Absent.
Cretaceous	......	Greensand	Postlebury.
Jurassic	Upper Oolite	Coral Rag	Absent.
	Middle Oolite	Oxford Clay	Cloford.
	Lower Oolite	Cornbrash	Cloford, Marston Bigot.
		Forest Marble	Chickwell, Faulkland.
		Bradford Clay	Bradford.
		Bath Oolite	Coombedown Lansdown P.
		Fuller's Earth	North Stoke, Lansdown, Box.
		Inferior Oolite	Dundry, Cotteswold Hills.
Liassic	Upper Lias	Liassic Sands	Dundry, Midford, Frocester.
		Upper Lias Clay	Dundry, Midford, Frocester.
	Middle Lias	Marlstone	Dundry, Sodbury, Stinchcombe.
		Clays	Dundry, Sodbury, Stinchcombe.
	Lower Lias	Clays	Horfield, Pell.
		Limestones	Keynsham, Saltford.
Triassic	Upper Trias	*Avicula contorta*	Aust, Beechum, Garden Cliff.
		Keuper	New River, Cotham.
		Dolomitic Conglomerate	Bristol, Portishead, Clevedon.
Permian	......	....	Absent.
Carboniferous	Upper	Coal Measures	Mangotsfield, Radstock, &c.
		Millstone Grit	Brandon Hill, Fish-ponds, &c.
		Upper Shales	Clifton, Ashton, Fish-ponds.
	Lower	Carboniferous Limestone	Clifton, Mendips, Tortworth.
		Lower Shales	Clifton, Clevedon, Tortworth.
Devonian	Old Red	Sandstones	Clifton, Portishead, Mendips, &c.
		Conglomerates	Clifton, Portishead, Mendips, &c.
Upper Silurian	......	Ludlow	Berkeley, Purton Passage.
		Wenlock	Tortworth, Falfield.
		Upper Llandovery	Tortworth, Damory.
Igneous Rocks.	......	Greenstone	Damory, Charfield, Woodford.
		Basalt	Uphill, Mendips, Weston.

The localities in this Table may be grouped into six districts:—

1. Tortworth district.
2. Mendip Hills.
3. Radstock district.
4. Bristol district.
5. Dundry district.
6. Bridgewater district.

1. Tortworth District.

Silurian.—Tortworth has long been classical ground to the geologist, and was first brought into notice by Dr. Cooke, formerly (1799–1835) rector of the parish. This gentleman made an extensive collection of fossils from all the rocks in the district, which after his death passed through my hands; and I can therefore speak to the fact. A description of the Geology of Tortworth was made by Mr. Weaver*, and by Buckland and Conybeare†. These memoirs were written at a time when the correlations of the then so-called Transition rocks were not understood; therefore they help us little toward a correct understanding of their age and character. It was not until Murchison had succeeded in making out the true relation and character of the upper fossiliferous beds beneath the Old Red Sandstone, and had arranged his groups by their organic remains in consecutive order under the name of the Silurian System, that the true age and relation of the Transition strata of Tortworth were understood. It then appeared that the Silurian rocks of Tortworth are the southern extension of the same formations which, extending through Micklewood Chase and the Vale of Berkeley, appear as a dome of Upper Silurian, rising near Tites Point on the left bank of the Severn near Purton Passage. The same rocks are found wrapping round the base of May Hill and Huntley Hill in the Forest of Dean, in the Valley of Woolhope, Herefordshire, on the western slopes of the Malvern Hills, and extending through Eastnor and Ledbury to Wenlock Edge, Salop. Whatever, therefore, is true relating to the Palæontological character of the Upper Silurians in these other localities, is equally correct of the same formations that lie in the miniature basin of Tortworth. The *Caradoc Sandstone*, or, as it is now called, the *Upper Llandovery Sandstone*, is the oldest rock at Tortworth, and forms the dominant stratum of the district. It covers an extensive area; and some small sections are seen at the south side of Micklewood Chase, and on both banks of the Avon near Damory Mill. Lithologically and palæontologically it is indistinguishable from hand specimens of the same formation at May Hill. It abounds in fossils: *Pentamerus*, *Strophomena*, *Orthis*, *Atrypa*, *Spirifera*, and *Leptæna*, with broken Trilobites belonging to the genera *Trinucleus*, *Calymene*, *Illænus*, and *Phacops*, are found, together with the stems of Crinoids and Tentaculites.

The *Wenlock Limestone* is exposed at Falfield Mill and Whitfield and other places; from its various beds the characteristic Upper Silurian Corals are collected, as *Favosites*, *Syringopora*, *Halysites*, *Porites*, *Caryophyllia*, and *Acervularia*. Crinoidal stems are very abundant. Many Brachiopoda (as *Leptæna*, *Atrypa*, *Orthis orbicularis*) and Gasteropoda (as *Euomphalus discors* and *Euomphalus funatus*) are collected, with fragments of *Calymene Blumenbachii* and *Phacops caudatus*. The *Ludlow Rock* is best exposed at low-water mark on the west bank of the Severn at Purton Passage, where it rises in a dome-shaped mass, and dips away beneath the beds of Old Red Sandstone of the Devonian series on the opposite shore; the upper portion of this formation consists of greenish-grey micaceous beds, with *Leptæna lata*, *Orthis unguis*, and *Terebratula Wilsoni*, which probably represent the Aymestry limestone.

Devonian.—The Old Red Sandstone, in its upper parts, consists of fine-grained thin flagstones of a whitish-grey colour; and Tortworth Court is built of these fine building beds. This upper division is underlain by coarse quartzose conglomerates, and at the base by red sandstone, which rests on the Llandovery strata. The same succession of beds is very persistent, with conglomerate in the centre and lower third, and sandstone above and at the base.

Carboniferous.—The Bone-bed at the base of this formation is well developed, together with the Lower Limestone Shales. *Psammodus linearis*, *P. lævissimus*, Coprolites, and *Pileopsis angustus*, Phil., a shell of the Carboniferous Limestone, are the leading fossils here.

Millstone Grit and Coal Measures.—These beds have been fully and accurately described in the 'Geological Transactions,' by Weaver, Buckland, and Conybeare, accompanied by many valuable sections. They consist of Millstone Grit, Lower Coal Measures, Pennant Sandstone, and Upper Coal Measures; the whole series may be studied and examined in this district. A section constructed from Tortworth Green to Frampton Cotterell gives the following:—Tortworth Green, Old Red; the Court and Park, Lower Limestone Shales; Ley Hill and Cromhall, Carboniferous Limestone; Cromhall Heath, Millstone Grit; Sweethouse, Lower Coal-Shales; Sweethouse to Robin's-wood House, Pennant, and from Robin's-wood house to Frampton Cotterell, Upper Coal Measures of the Coal-pit Heath basin.

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* Trans. Geol. Soc. vol. i. p. 317 (2nd series).

† *Ibid.* p. 210.

An able paper on this subject, with Map and Sections, by my friend Mr. Etheridge*, F.R.S., will be found in the papers of the Cotteswold Club.

Dolomitic Conglomerate.—Weaver described this formation as composed principally of "rounded and angular fragments of limestone exceeding the size of the head, with fragments also of quartz and hornstone. These are all cemented together by a calcareous paste, which is frequently of a marly nature—or of a carbonate of lime either of an earthy or compact structure;" the cement is generally magnesian, and in this there are many cavities frequently lined with crystals of calcareous spar and quartz, and also with the sulphate of strontian.

This remarkable formation forms a kind of irregular broken fringe, hanging on the flanks of the older rocks, and resting unconformably upon them. We shall meet with this conglomerate again in connexion with the beds in the Mendip Hills and in the Clifton section.

New Red Sandstone.—The upper and central members of the New Red Sandstone are found near Tortworth; they consist chiefly of red clay and marl.

Avicula-contorta beds have been found by the Earl of Ducie in the form of the Bone Bed, the series resting on the inclined edges of the Carboniferous Limestone.

2. MENDIP HILLS.

The Mendip Hills proper extend from Bleadon Hill near Hutton on the west, to Elm and Whatley on the east; and they strike nearly due west and east, and are about 30 miles in length, with an average breadth of 5 to 6 miles. They constitute the southern base of the Bristol Coal-field, or the base of an almost equilateral triangle, formed by the Palæozoic rocks, comprising the area from Purton Passage and Tortworth to the south slopes of the Mendips; this includes the outlier Bream Down, which is only a westerly prolongation in the Severn, separated from the main range of the Mendips by the alluvial flat of the estuary of the Axe.

The Lithology of the Mendips consists of Old Red Sandstone, Carboniferous Limestone, and Trias, the latter represented chiefly by the Dolomitic Conglomerate, which lies unconformably on the Old Red and Carboniferous, flanking nearly the entire range of hills, and in places capping their summits.

Numerous islands of Carboniferous Limestone surrounded by Triassic rocks occur east of Wells and south of Croscombe, also encircled by fringes of Dolomitic Conglomerate, of which Church Hill, Worminster, and Knowl-foot Hill are examples; these outliers testify to the southern extension of the Carboniferous Limestone beneath the New Red Sandstone and Lias south of the Mendips, and lend us aid in determining the probable position of deep-seated Coal Measures similar to those at Vobster, Colford, Edford, Holcombe, &c., north of the Mendip range.

The lower flanks of the northern portion of the range are covered by the New Red Sandstone, that of the south being a mere strip traversed by the Wells-and-Axbridge Railway, the peat plains and bogs of Sedgmoor covering them up to a certain level to the east of the meridian of Glastonbury. The Lias occupies an extensive plain, masking likewise the older rocks beneath.

Old Red Sandstone forms the oldest stratified rock, and is, strictly speaking, the axis of the Mendip Hills. It is exposed in four well-marked areas along the highest ridge:—(1) Blackdown; (2) North Hill and Pen Hill; (3) Beacon Hill; and (4) Downhead Common, which is the largest exposed tract. The intervening areas are occupied by a mantle of Carboniferous Limestone, which arches over and covers the underlying Old Red, denudation having yet spared the limestone.

The Old Red is exposed along two anticlinal axes, these being, indeed, the chief cause of its exposure; the axes being post-Carboniferous and pre-Triassic, are not traceable beneath or where the patches of Dolomitic Conglomerate and cherty Lias cover up the Old Red Sandstone and Carboniferous Limestone, as at Harptree Hill, Rowham, Shipham, &c.

The most northerly anticlinal brings up the fine range of Blackdown, on the north, south, and east of which occur the Lower Limestone Shales resting on Old Red.

The northern dip of the anticlinal is higher than the southern, being in places as high as 54° in the north, whilst in the south it does not exceed 20°. This anticlinal is traceable from near the exposure of the igneous rock at Uphill, along Bleadon Hill, thence under the New Red Sandstone to Padingham, and Dolomitic Conglomerate and Calamine beds of Shipham, through the Old Red Sandstone of Blackdown, and on through the Carboniferous Limestone of Lamb-bottom, where it is lost under the cherty Rhætic beds of Harptree Hill. From Little Elm on the extreme east to Masbury Castle nearly due west of the range, the Old Red is again exposed for three miles, which is likewise due to the anticlinal axis.

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* Proceedings of the Cotteswold Naturalists' Field Club, p. 28 (1865).

At Masbury Castle we lose trace of this S.E. anticlinal, and a second and parallel one to that of Blackdown occurs, ranging from the Old Red of North Hill through the Carboniferous Limestone of Stoke Warren, and last under the dolomitic conglomerate of North Draycott. This may join the great anticlinal near Egar Hill. We thus see that the strike of the Mendips was induced by a force which has brought out its oldest rock to the surface, and thereby produced the present physiography of the bold range of hills we are now considering.

Carboniferous Limestone surrounds the exposed and concealed nucleus of Old Red, and is conformable therewith both in dip and strike. The Carboniferous Limestone has grand development in the Mendips, and constitutes the great mass of the chain, having a continuous spread of five miles between Westbury Beacon and Abley, also between Croscombe and Emberrow. The Lower Limestone shales are nowhere more finely exposed than around and resting on the upper members of the Old Red Sandstone, and are highly fossiliferous throughout, the beds being crowded with *Strophomena*, *Chonetes*, *Spirifera*, Polyzoa, the ossicula of Crinoids, and many Trilobites, presenting a strong contrast to the barren beds of the Old Red on which they conformably rest. The Shales are well developed around Blackdown, especially to the east of Charterhouse, at Rowbarrow and Priddy, west of North Hill, and Nine Barrows; and east of Egar Hill they attain a thickness of 500 feet, and are extremely rich in organic remains. They present an extended outcrop from Masbury to Stoke Lane, and Leigh upon Mendip, and in the Downhead beds near Asham Woods. The local development of these argillaceous beds of the lowest division of the Carboniferous Limestone first gave origin to the name Lower Limestone Shales. They are almost special to the west of England, and are exposed on both flanks of the Mendip range. On them rest the thick-bedded strata of the Carboniferous Limestone, which is everywhere traceable for thirty miles from Oldford, the gorge of the Vallis to Elm on the east, to the distant headland of Bleadon in the west, and everywhere abounding more or less with organisms which form the leading fossils in its beds.

Coal Measures.—On the northern flank of the Mendips, between Binegar and Wells, and resting on the Millstone Grit, highly faulted and contorted, are the well-known Coals of Vobster, Holcombe, Pitcot, &c., that portion on the west at Stratton on the Fosse, Downside, &c. being covered by Dolomitic Conglomerate, the eastern side at Newbury and Vobster being overlain by the same rock and the Inferior Oolite. There is no reason why we should not conclude that the Coals of the northern side once extended across the Mendips and now lie deeply buried along the south parts of the range. At Ebber rocks, west of Wells, we have evidence of the Millstone Grit resting on the Carboniferous Limestone; and the elevation of the Mendips being post-Carboniferous, lends an additional reason for the occurrence of the Coals of the northern area to the south of the Mendips, and beneath the Lias and Peat plain of Glastonbury, Castle Carey, the Pennards, and the Poldon Hills. No Coal area in the United Kingdom is so disturbed and folded both along its strike and on the dip of the Coals as those of North Mendips; and like the Coals of the "Mons Coal-field" in Belgium, which exists under similar conditions, the seams are vertical and thrown over, so that the same seams are passed through by shafts two or three times. The Vobster and Holcombe Coal-seams are the same as those at Ashton and Kingswood near Bristol, Twerton near Bath, and probably the same as those at Yate. They underlie the whole area between the Mendips and Bristol, and are probably the same that occur at Kingswood and underlie the Pennant at Coal-pit Heath.

The Trias.—Two divisions of this group are greatly developed around and upon the Mendips, especially the inferior or Dolomitic Conglomerate, a peculiar and local condition of the base of the Keuper Sandstone of the Bristol and South Wales Coal-fields, chiefly that portion of the latter which extends from Cardiff to Bridgend. The entire range of the Mendips is surrounded by Dolomitic Conglomerate; and ten or twelve patches still remain as unconformable undenuded masses of that formation resting upon the older rocks forming the massive range of the Mendips. This remarkable deposit completely covered the range when at a lower level, its partial removal being conclusively shown by the remnants that still cling to the steep face of the northern and southern flanks of the Mendips.

This Conglomerate is composed entirely of greater or lesser fragments of the older rocks composing the hills, and is the result of the denuding action of the sea that deposited the Keuper Beds. This marine denudation took place when the entire area occupied by the Mendips and Coal-basin underwent depression, the Dolomitic Conglomerate and sandstones accumulating *pro ratâ* with the depression and consequent destruction of the rocks offered for resistance. This conglomerate, the "*overlie*" of the coal-miners of the Bristol basin, although visible only upon the Palæozoic rocks surrounding the coal-bearing area, is nevertheless entirely spread over them, and beneath the New Red Sandstones that occupy nearly the entire area from Tortworth to the southern flanks of the Mendips, its presence being marked by the marls and sandstones of the Keuper, the Lias limestones, and in other places the Oolitic rocks that lie within the Coal-basin, especially along its south-east border from Bath to Wells. We have no physical evidence more convincing of denudation, elevation, and depression over large areas of the earth's surface than what we can witness so easily and study so advantageously in the Mendip Hills; for this conglomerate rock here defines the limits between Mesozoic and Palæozoic times: the highly inclined Old Red Sandstone forms the nucleus of the chain, the Carboniferous rocks resting upon it; and the Coal Measures in conformable succession to the latter were all indurated, metamorphosed, elevated, and thrown into folds long prior to the time when, under slow depression, destruction, and denudation, the Dolomitic Conglomerate was laid down by the Triassic Sea—the resultant of wave forces along a coast-line which was then the Mendip range, its shingle and boulders being slowly cemented by a magnesio-calcareous paste derived from the wasting beds of the great limestone series. For further details regarding the natural history of the Dolomitic Conglomerate I must refer to a valuable memoir on this formation by Mr. Etheridge, F.R.S.*

The Rhætic.—Singular beds of cherty and sandy deposits of Rhætic age occur in several parts of the Mendips, in places brecciated, or as a conglomerate, and resting either upon the Dolomitic Conglomerate or Carboniferous Limestone.

The fossils are either cherty, or they have been removed, and their moulds are formed of chert, or cavities are left where organisms existed.

These beds are exposed at East Harptree, Egar Hill, Ashwick, and Shepton-Mallet. In the Vallis they repose immediately on the upturned edges of the Carboniferous Limestone, and even fill in the numerous veins, pockets, and faults in that formation with fossil species common to the beds.

Nowhere can the geologist read more clearly the physical history of the groups of associated rocks composing the structure of the Eastern Mendips than at Wells, the Vallis, Watley, Elm, Nunny, and Holwell, where Old Red Sandstone, Carboniferous Limestone, Coal Measures, Dolomitic Conglomerate, Rhætic Beds, Lias, and Oolites are all exposed in natural sequence to each other. There can be no doubt that the Rhætic Sea surrounded and covered the Mendips; for its remains are found reposing on the Old Red Sandstone, Carboniferous Limestone, Coal Measures, and Dolomitic Conglomerate, and pass upwards into the Lias beds.

The Lias.—Fragmentary portions of this formation are found resting upon the summits of the Mendips, covering respectively Old Red Sandstone, Carboniferous Limestone, Dolomitic Conglomerate, and Rhætic beds, and in the Holcombe and Barrington districts resting upon the Coal Measures, proving the former extension of the Liassic Sea over the Mendips; for upon some of their highest points, as near as Castle Comfort, the cherty beds, with their characteristic fossils, are found; also at Chewton Mendip, Emberrow, and Ashwick, &c.; and on the south side of the hills it is found at a considerable height, as at Downside, Chilcott, and West Herrington. During the Lias age the Mendips must either have been an archipelago, or they were totally submerged beneath the sea which deposited the Liassic plain to the north and south. The re-elevation of the Mendip range has occasioned the removal by aqueous denudation of most of the Lias beds deposited on their summit, whilst along the southern flanks of the hills, and in the valley, a considerable thickness of this formation still remains *in situ*.

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* Quart. Journ. Geol. Soc. vol. xxvi. p. 174 (1870).

Igneous Rocks.—Mr. Charles Moore* has shown that there is an exposure of basaltic rock (dioritic) along the anticlinal of the Mendips, a little west of Downhead, extending visibly nearly as far as Beacon Hill, between two and three miles in length and a quarter of a mile in width.

This igneous mass appears in the form of a dyke, and is coincident with the anticlinal line along the axis of the Mendips, which is here traceable for seven miles, and is again continued from near Harptree to Shipham.

There is likewise at the south end of Uphill cutting (Bristol and Exeter Railway), at the western extremity of Bleadon Hill, an extensive patch of igneous rock, discovered when that line was made, and described by Mr. W. Sanders, F.R.S.; this exposure was also in the line of the anticlinal, and ended in the fault which there crosses the line. This rock, according to Mr. Rutley's analysis, is a Pitchstone Porphyry, whilst Mr. David Forbes considers it a Dolerite.

Whether this dyke was really eruptive or overflowed the Old Red Sandstone is still a question to be solved; and whether it is coextensive with the range is unknown; but its age must be subsequent to the Coal Measures—the whole of the Palæozoic rocks being disturbed alike, and lying at one general angle of inclination, the overlying secondary strata not being influenced or at all affected by these Palæozoic changes. The Old Devonian rocks in contact with the dyke are not altered or metamorphosed, thus establishing the facts of age and condition.

3. THE RADSTOCK DISTRICT.

Among the many interesting features of the neighbourhood in which we are assembled is the Bristol Coal-field, which still offers an inexhaustible subject for scientific inquiry—extending from Cromhall in the north to Frome in the south, and from Bath in the east to Nailsea in the west, comprising an area of 238 square miles.

From a very early date it attracted the attention of geologists, and was long ago he subject of a paper by Mr. Strachey, which was published by one of the local ocieties. Dr. Buckland† contributed an able memoir on this Coal-field, in which a great quantity of important information was placed on record, which has been of the greatest possible use down to the present time.

Subsequently this area has formed the subject of able papers contributed to the North-of-England and South-Wales Institutes of Engineers, by Mr. J. C. Greenwell, F.G.S., and Mr. Handel Cossham, F.G.S., and to other scientific societies by Mr. Robert Etheridge, F.R.S., and Mr. Charles Moore, F.G.S.

During the past twelve years Mr. J. M'Murtrie, F.G.S., of Radstock, has been coninuously engaged in working out the physical geology of the district, and has conributed a series of memoirs on the Bristol Coal-field to the Bath and Somersethire Societies, which have thrown a new and important light on those marvellous disturbances which have distorted the strata.

That part of the Report of the Royal Coal Commission bearing upon the Bristol Coal-field and prepared by Professor Prestwich, and papers by Mr. Horace Woodward and Mr. John Anstey, have summarized our previous knowledge, and added recent facts thereto; but with all that has been done much remains to be investigated before a full history of the Bristol Coal-field can be written.

Although more or less connected throughout, the Coal-fields adjoining Bristol conist of three well-defined areas, called the Gloucestershire, Radstock, and Nailsea basins, each of which has its own distinctive features. The Gloucestershire is eparated from the Radstock basin by the great Kingswood anticlinal, which interects in a ridge-like form the entire Coal-field from east to west; and the Nailsea basin has been almost, if not entirely, cut off from the principal coal district by the elevated limestones of Broadfield Down. Of these three areas Radstock basin is the most extensive, both geographically and sectionally, a great portion of its thickness being yet entirely undeveloped. One of the features which will be remarked by visitors coming from other parts of England is the number and character of the Secondary formations by which the Radstock basin is overlain. Here and there, it is true, Mesozoic rocks have been denuded; but by far the greater portion of the Coal-field is hidden beneath a covering of New Red Sandstone, Lias, and Inferior Oolite, and many of the shafts have had to pass through all these formations before the coal-seams were reached.

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* Quart. Journ. Geol. Soc. vol. xxiii. p. 452 (1867).

† Trans. Geol. Soc. 2nd series, vol. i.

A very slight change in the geological circumstances of the past would have left us in entire ignorance of the existence of a Coal-field so far south as Bristol; and this reflection induces the hope that in other parts of our country (at present believed to be without coal, or, if present, to lie at such a depth from the surface that it cannot be worked) it may yet be discovered at a moderate depth.

Another feature of the Radstock Coal Measures is their great thickness, which Mr. M'Murtrie estimates at 8000 feet. From this we may infer that, however limited the area in Somersetshire of which we have at present positive knowledge, we are very far indeed from the edge of that infinitely more extensive area which the Coal Measures of the south of England originally occupied, and within which outlying basins may still be found.

It is abundantly evident that the Bristol Coal-field was originally connected with that of the Forest of Dean and South Wales, with which it has many characters in common, although it differs in other respects.

In all we find the same arrangement of the different strata, namely:—1st, an upper division of productive Coal Measures; 2nd, a central mass of Pennant Sandstone; and, 3rd, beneath, a lower division of productive Coal Measures resting upon, 4th, the Millstone Grit. Hitherto it has been found impossible to correlate the seams of coal; but they present many points of general correspondence in the districts referred to; and the information obtained leads to the conclusion that their greatest sectional development occurs between Radstock and Bristol, according to the following estimate of the thickness of the strata, number of seams, and thickness of coal-seams:—

Table II.—Strata and Coal-Seams.

Division of Strata.	Sectional thickness.	Number of Coal-seams.	Thickness of Coal-seams.	
			feet.	inches.
Upper Coal Measures....	2600	16	26	10
Pennant Sandstone......	2750	4	5	10
Lower Coal Measures ..	2800	26	66	6
	8150	46	97	26

This great sectional thickness is attended, however, with serious disadvantages; for although, according to the Report of the Royal Coal Commission, the Bristol Coal-field was estimated to contain 6104 millions of tons of coal, a large portion of it lies at an unworkable depth. Another physical feature of the district is the thinness of many of the seams from which coal is at present obtained.

In many of the collieries seams of from 10 to 12 inches in thickness are extensively worked, thus setting a good example of economy of one of our most precious natural productions to other parts of England, where veins of similar thickness are left behind as worthless.

Another feature of the Radstock Coal-basin is the extreme richness of its beds in the fossil flora of the Coal Measures. The Pennant Sandstone and Lower Measures yield few plants; but the Upper divisions contain much finer specimens than I have seen elsewhere; and the fossil flora of Radstock preserved in Mr. M'Murtrie's Museum is alone worth a journey to study and admire. The fossil ferns are in great variety and beautifully preserved. The *Sigillariæ*, *Lepidodendra*, and other acrogenous stems tell of the arborescent ferns that floated their plume-like foliage on the islands of the Carboniferous period, and the industry and genius of the man who has collected and preserved them for our instruction and delight. The animal remains are here very scarce; two or three species of the genus *Limulus*, and one or two *Anthracosiæ*, are all that have been found: and I have the satisfaction of adding that I am authorized to say that by previous arrangement Mr. M'Murtrie will be happy to show his Museum to any Members of the Association to whom the same might be interesting. As there will be, I understand, memoirs on the Radstock Coalfield, I must refer to these papers for further details on this interesting district.

4. THE BRISTOL DISTRICT.

In a radius of eight miles from the Guildhall we find exposures more or less complete of the following Palæozoic and Mesozoic formations:—1. *The Old Red Sandstone*; 2. *The Carboniferous Limestone*; 3. *Millstone Grit*; 4. *Coal Measures*; 5. *Dolomitic Conglomerate and New Red Sandstone*; 6. *Rhætic*; 7, *Lias, Lower, Middle, Upper*; 8. *Upper Lias Sands*; 9. *Inferior Oolite*; 10. *Fuller's Earth*; 11. *Great Oolite*; 12. *Alluvium*, with igneous rocks of Palæozoic age. Several of these formations I have already noticed in speaking of the Mendip Hills; therefore I shall now only add such special remarks as are required to complete their sketch in the Bristol district.

The *Old Red Sandstone* forms, as we have seen, the axis of the Mendip Hills, and here occurs as a massive rock in different regions of the Bristol Coal-field, forming ranges of hills that have been sculptured by denudation out of its anticlinal folds. The beds in general are very unfossiliferous.

In the neighbourhood of Portishead, however, the remains of some large fishes have been found in a hard conglomerate, belonging to the genus *Holoptychius*—reminding us of the fishes of the Old Red Sandstone of Scotland, which were all encased in a bony armour, and possessed some of the most remarkable forms of the ichthyic type. *Pterichthys* or wing-fish, *Holoptychius* or wrinkle-scaled fish, *Cephalaspis* or buckler-shielded fish are all forms of the Old Red, and the earliest representatives of the class Pisces in the Palæozoic rocks.

The Carboniferous Limestone is a great marine formation, and is formed of the sediments of an extensive and wide-spreading sea; the beautiful scenery so characteristic of the Avon, Severn, and Wye is in a great measure due to the development of this rock in these regions. One of the grandest sections of all the beds of the Carboniferous Limestone is that exposed in the gorge of the Avon near Clifton, where it is seen resting on the Old Red Sandstone, and overlain by the Millstone Grit.

The various conditions of the old sea-bottom in which this mass of calcareous rock was formed may here be studied with ease. The entire thickness of the strata exposed is upwards of 4000 feet; of this the Old Red Devonian is 768 feet, the Carboniferous Limestone 2338, and the Millstone Grit 950 feet. This magnificent section has repeatedly been the subject of memoirs by Buckland*, Conybeare†, Bright‡, and Williams§, who have given ample details of all its different beds.

The Lower Limestone Shales, 500 feet in thickness, are very fossiliferous; they consist of alternations of shales and limestone, with a bone-bed near their base; in some places beds several feet thick are formed of the ossicula of Crinoids. In the main Limestone series you have a succession of Brachiopoda; *Spirifera*, *Producta*, and *Orthis* follow each other. Of Lamellibranchs we find *Aviculopecten*, *Cardiomorpha*, &c., with Gasteropods, as *Euomphalus* and *Bellerophon*, and Cephalopods, as *Goniatites*, *Orthoceras*, *Actinoceras*, &c. To these may be added the teeth and defensive spines of large shark-like and other fishes, as *Cladodus*, *Psammodus*, *Orodus*, *Holoptychius*, &c. Some of the coral strata in the upper part of the series are very interesting, and extremely rich in very beautiful specimens of Actinozoa, belonging to the reef-building groups of the ancient sea, as *Michelinia*, *Amplexus*, *Lithostrotion*, *Syringopora*, *Lonsdaleia* &c., reminding us of the structure of coral reefs in our present seas. Associated with the coral masses are other organisms which lived on the reefs or in shallow lagoons. The coral beds are covered by strata formed of Oolitic limestone and other detrital materials derived from the débris of wasted reefs, and formed along the shores of the ancient coral strand; sections of these oolitic beds prepared as slides for the microscope disclose the fact that the nucleus of the oolitic granules is often the shells of Foraminifera.

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* "On the South-Eastern Coal District of England," Geol. Trans. 2nd series, vol. i.

† Geol. Trans. 1st series, vol. iv.

‡ "On the Limestone Beds of the River Avon," Geol. Trans. 1st series, vol. v.

§ 'Memoirs of the Geol. Survey,' Sir H. De la Beche's Essay, vol. i. p. 113.

Millstone Grit is well seen at Brandon Hill; it rests upon the Limestone, and attains a thickness of 1000 feet. On this repose the Coal Measures of the Bristol Coal-field, which I have already described in connexion with the Mendip and Radstock districts.

Dolomitic Conglomerate.—The Palæozoic rocks of the Bristol Coal-field are here and there covered over by patches of Dolomitic Conglomerate lying unconformably on their upturned edges, at heights varying from 20 to 300 feet above the Avon. This remarkable formation is very well seen in the new road leading from the Hotwells to Clifton and Durdham Down. It has been long well known to geologists, and was in former days described by Bright, Gilby, Buckland, and others.

Rhætic.—Between the uppermost beds of the grey marls of the Keuper and the lowest beds of the Lias there lies a remarkable assemblage of strata, which I formerly described * as the "*Avicula-contorta* beds," from that shell forming the leading fossil therein. The name Rhætic has since been given to the series, from a supposition that the beds are identical with some that occur in the Rhætian Alps, which is, however, more than doubtful. Typical sections of the *Avicula-contorta* series are exposed at Garden Cliff, Aust Cliff, Penarth, and Watchet on the Severn, and at Weston, Keynsham, Willsbridge, and Saltford near Bath, and Puriton, Uphill, and Wells in Somersetshire, as well as at many other localities. Two of the most classical of the series are Garden Cliff and Aust Cliff; the latter has been long known to continental geologists as the Bristol Bone-bed. In the upper part of the section are dark grey shales, intersected by bands of limestone; *Avicula contorta, Cardium Rhæticum, Pecten Valoniensis, Axinus,* &c. are found in these. The Bone-bed consists of a hard dark grey siliceous grit full of the bones, spines, scales, and teeth of fishes belonging to the genera *Nemacanthus, Acrodus, Sargodon, Hybodus, Ceratodus,* &c. Beneath this thin Bone-bed with its ichthyic débris is a bed of shale which rests upon the grey marls of the Keuper. A similar succession of strata is repeated in most of the other typical sections. I have named especially those at Garden Cliff, Penarth, Uphill, and Watchet.

Aust has been long famous for its *Ceratodus*-teeth, and is, I believe, the only locality where they are collected. You will find a fine series of them in the Bristol Museum. This wonderful collection is quite unique and will well repay an attentive examination.

The only living representative of the genus *Ceratodus* now lives in the rivers in Queensland; and a fine specimen was lately purchased for and presented to the Museum by W. W. Stoddart, Esq., F.G.S., for the purpose of showing the comparative size of the recent and fossil teeth.

5. DUNDRY DISTRICT.

The Oolitic Formations.—The Oolitic formations will long remain classical ground of English geologists, as it was whilst studying these rocks in Wilts and Somerset that Dr. William Smith first acquired that knowledge which enabled him to "identity strata by organic remains," and establish a true natural system of stratigraphical geology.

The Oolitic period admits of a subdivision into three groups—the Lower, Middle, and Upper; each group is based on a great argillaceous formation, on which rest minor beds of sands and cream-coloured Oolitic and Pisolitic limestones. The Argillaceous formations form broad valleys, extending diagonally across England in a direction north-east by south-west. The limestones constitute low ranges of hills, with escarpments facing the south-west and overlooking the valleys. The Lower Oolites rest on the Lias, the Middle Oolites on the Oxford Clay, and the Portland and Upper Oolites on the Kimmeridge Clays.

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* Quart. Journ. Geol. Soc. vol. xvi. p. 374.

The *Lias Formation* is well developed around Bristol; and many interesting and instructive sections of the Lower beds may be studied at Horfield, Keynsham, Saltford, and Weston, whilst the Middle and Upper divisions are exposed in other localities. It has been often repeated of late years that the geological record is imperfect, and that many of the leaves, and even whole chapters of the Rock-book on which the hieroglyphics of its history were written, are wanting; yet "Time which antiquates antiquities, and hath an art to make dust of all things, hath yet spared these minor monuments;" for it is certainly true that the Jurassic formations contain a marvellously complete record of the succession of life in time during their deposition from the dawn of the Lias until the close of the Coral Sea, amid whose islands fossil *Cycadeæ* luxuriantly flourished, and whose remains are buried in their native Dirt-beds in the Portland Oolites.

I have shown elsewhere that the three divisions of the Great Lias formations admit of several subdivisions or zones of life, each characterized by a group of species which individualize it. A careful examination of these subdivisions has further proved that there is no confusion in the rocks when carefully examined—that Nature is always true to herself, although all geologists are not true to Nature. The fossils of the Lower Lias are quite distinct from those of the Middle Lias, and both specifically different from those of the Upper.

The *Ammonites* are important leading Liassic shells, that appear to have had a limited life in time, but a wide extension in space; and they have greatly aided us in determining periods and making out the history of the Liassic Sea. The great SAUROPTERYGIA, represented by the *Plesiosaurus*, and the ICHTHYOPTERYGIA by the *Ichthyosaurus*, are remarkable forms of Reptilia adapted to the waters of that epoch, whilst the DINOSAURIA, represented by *Scelidosaurus*, the PTEROSAURIA by the *Pterodactylus*, lived in this area during the Lias age: magnificent specimens of these different forms of reptile life adorn the walls of the Bristol Museum.

The Jurassic Age.—Dundry Hill, 700 feet in altitude, is the most westerly outlier of the Oolitic range, from which it is nine miles distant. It is a locality of great interest to the local naturalist, as it affords capital lessons of stratigraphical geology, admirable examples of surface-rock sculpture by denudation, and a commanding point of view for surveying the same, and showing the grand panorama in the midst of which it stands. The greater portion of the Hill is composed of Lower Lias strata, which are well exposed at Bedminster Down, Whitchurch, Keynsham, Queen Charlton, Norton, Malreward, Winford, and Barrow. The beds consist of alternations of limestones and shales, having a total thickness of 550 feet. The Middle Lias and Marlstone are feebly developed, and the Upper Lias represented by some thin clays, with dwarfed specimens of *Ammonites bifrons* and *A. communis*; and the Upper Lias Sands, from 1 to 2 feet thick, are not fossiliferous. On these rest beds of Inferior Oolite rock which have long yielded a very fine series of organic remains, some of the best of which are now preserved in the Museum collection. The Inferior Oolite of the south of England admits of a subdivision into three zones of life: the *Lower*, resting upon the Lias Sands, has the *Ammonites Murchisonæ* as its leading fossil; the *Middle* contains a large assemblage of Mollusca, and especially of *Ammonites*, among which *Ammonites Humphriesianus*, *Sowerbyi*, *concavus*, and *Blagdeni* are conspicuously characteristic; the *Upper* contains *Ammonites Parkinsoni*, *Martinsii*, and *subradiatus*, with many Echinoderms and a large series of reef-building corals. These three subdivisions are rarely all developed in the same section; but the order of their sequence in nature is as stated in Dundry. The lower beds are feebly represented; and there is an immense development of the middle and upper divisions.

In the iron shot shelly beds there is a fine assemblage of Lamellibranchs; and the stratum which covers then is very rich in Ammonites, many with their shells preserved, and having their oral lobes and other appendages *in situ*.

These are succeeded by other conchiferous strata; and the whole is covered by Ragstone and Building-stone, forming the upper zone, with *Ammonites Parkinsoni*, *Echinidæ*, and Corals. The stratigraphical, lithological, and palæontological conditions seen in the Oolitic capping of Dundry Hill are repeated in other localities in Gloucestershire, Somersetshire, and Dorsetshire; and a full development of all the zones in actual superposition may be examined in certain sections in the Cotteswold Hills, as at Leckhampton and Cleeve.

The Fuller's Earth must be studied at North Stoke and Lansdown, and the Great Oolite at Coombedown, Lansdown, and other localities around Bath; the typical Bradford clay, with Apiocrinital heads and stems and beautiful Brachiopoda, near Bradford; the Forest Marble and Cornbrash at Faulkland, Chickwell, Marston Bagot, and Cloford. The Middle Jurassic rocks are admirably exposed near Calne, and the Upper Jurassic near Swindon, Wilts.

The great importance of the Bristol district as a source of mineral wealth, added to the complicated structure of this region, led my old friend Mr. William Sanders, F.R.S., to construct an elaborate geological map of the Gloucestershire and Somersetshire Coal-fields and adjacent country, on the scale of four inches to a mile. The topographical portion of this undertaking was reduced to one scale from the Tithe-Commission Maps; and Mr. Sanders traced out all the geological boundary lines in the field, and laid them down in MS. copies of the Tithe Maps, making copious notes of the strata as he proceeded with his work. The whole was finally reduced to one scale four times the size of the Ordnance-Survey Maps, and reproduced with the most scrupulous care by Mr. Stratton, who for many years assisted Mr. Sanders with the work which he had made the chief object and occupation of his later years; and it is but simple justice to say that, single-handed, no such exact map for any one area was ever before constructed, either as regards scale or details. This undertaking occupied its author 15 years, fills 19 separate folio maps, and is a most valuable acquisition to the estate-agent, mineral engineer, and practical geologist. Its real merits can only be fully appreciated by those who understand how much patient labour, long-sustained energy, and high mental qualities were required to complete so extended a survey over such a complicated piece of country. In doing this, however, Mr. Sanders has made his scientific reputation, enriched his native city, and achieved a success which falls to the lot of few men. Having considered the stratigraphical relation of the rocks in the Bristol district, I desire now to say a few words on a branch of the subject which falls more immediately within the range of my own special studies, I mean the organic remains found imbedded in these strata. The science of Palæontology forms an immense field of observation, and one that widens more and more every year. It is impossible to enter upon any of its details now; but some of its principles may be satisfactorily explained, and this I shall endeavour to do.

It is now established, 1st, that the stratified rocks containing organic remains admit of a division into four great groups, representing four great periods of time:—*a*, the Palæozoic or Ancient; *b*, the Mesozoic or Middle; *c*, the Cainozoic or Tertiary; and *d*, the Quaternary or Modern periods. 2nd. That each period is distinguished by its own hieroglyphic characters, which are engraven on the rocks in definite and determinable characters. 3rd. That these hieroglyphics are the fossil remains or imprints of animals that lived in the water in which the sediments were formed in successive layers on the earth's crust, and are only found in the rocks they distinguish; so that it is possible to determine the age and position of the strata from which they have been collected, or, in other words, *identify strata by organic remains*; and by this key are we enabled to read the pages of the Rock-book, study the history of extinct forms of life, and determine their distribution in time and space.

Let us apply these principles to the subject we have in hand. The Palæozoic period comprises the history of the Cambro-Silurian, Devonian, Carboniferous, and Permian ages; and if we attentively examine the fossils of this period contained in the cases of the magnificent Geological Museum of this institution, we shall see that all the organisms belonging to one age are entirely distinct from those belonging to the others. You will find, for example, in the case of the Silurian age, some beautiful corals, crinoids, and cephalopods, with a remarkable assemblage of crustacea, the representatives of an extinct family, the Trilobitidæ, which are so highly characteristic of this age that the rocks may be called Trilobitic.

The Devonian age succeeds the Silurian; and among the corals and shells so well seen in this Collection we observe a striking resemblance to those of the Silurian on the one side and the Carboniferous Limestone on the other; but when closely examined we find that many are generically, and all are specifically distinct from both; besides this we discover that a new group of organisms of a different and higher type of structure are now introduced for the first time—namely, those remarkable forms of the ichthyic class the fishes of the Old Red Sandstone, and whose singular forms with their bony armour and osseous scales remind us of the remarkable fishes *Lepidosteus* and *Polypterus* from North-American, African, and Australian rivers of our time. The hieroglyphics, therefore, engraven on the strata of the second age are visibly different from those on the first.

The Carboniferous succeeds the Devonian; and here we find a marvellous development of the life of this age preserved in the cases of this Institution. Pray study attentively the fine specimens of Anthozoa here exhibited, all derived from the upper beds of the Carboniferous Limestone at the gorge of the Avon, and showing very clearly that this portion of the section was formed in a tropical sea, and that the limestone is the product of the living energies of those Polyps, sections of whose skeletons lie there before you. Of the family FAVOSITIDÆ we see *Favosites*, *Alveolites*, *Syringopora Michelinia*; and of the family CYATHOPHYLLIDÆ we have *Cyathophyllum*, *Lithostrotion*, *Lonsdalia*, &c. Many of the beds of limestone are almost entirely composed of the ossicula of Crinoids; and we see the stems, arms, and calyces of these sea-lilies strewed in abundance in the rocks, such as *Actinocrinus*, *Poteriocrinus*, *Platycrinus*, *Cyathocrinus*, *Pentremites*, &c., with the remarkable ancient Sea-urchin *Palæchinus* associated with them. The Mollusca were chiefly represented by the Brachiopoda, which were very common in the Carboniferous age, as you may see in the large slabs containing *Orthis*, *Spirifera*, and *Productus* in great profusion. The Lamellibranchiata were represented by *Cardiomorpha* and *Conocardium*, and the Gasteropoda by *Euomphalus*, *Pleurotomaria*, and *Natica*, and the Cephalopoda by *Goniatites*, *Orthoceras*, &c. The Trilobites, which formed so remarkable a feature in the fauna of the Silurian sea, are here represented by a few specimens of *Phillipsia*, a dwarfed genus of this family. The fine collection of teeth and spines of large fishes from the Carboniferous Limestone enables us to compare the forms of this age with those of the Devonian already described, and shows at a glance that the ichthyic types in the seas of these two periods were entirely distinct, and both evidently adapted to conditions of existence widely different.

The life of the Carboniferous Limestone proves that it was a great marine formation accumulated during a long lapse of time out of the exuviæ and sediments of many generations of Mollusca, Echinodermata, and Actinozoa, the reef-building corals having contributed largely to the thickness of the Coral-beds, and the wasted reefs of former generations having been used up again and again in the formation of the Oolitic beds which succeeded the reef-building periods.

The Coal Measures present a remarkable contrast to the Coral sea of the Carboniferous era. The Ferns (*Sigillaria*, *Lepidodendra*) and other arborescent Acrogens of the Coal-seams grew and flourished in low islands; and their remains were accumulated under conditions very different from those in which the thick-bedded limestones of the Avon section were formed. Good typical examples of the vegetation of this remarkable time in the world's history are well preserved in the large collection, filling several cases; these specimens are all very fine, and require, and I am sure will have, a careful examination.

With the close of Palæozoic time there appears to have been a great break in the stratigraphical sequence of the fossiliferous rocks; mighty changes then took place. Volcanic agency was intense and active, flexing, contorting, and upheaving the older beds. These displacements in our area were post-carboniferous and pre-triassic, and are well exemplified in the unconformable position of the Dolomitic Conglomerate and New Red Sandstone of the Bristol district.

The dolomitic conglomerate contains the bones of Dinosaurian reptiles discovered in Durdham Down, and preserved in this Museum; they were described by Dr. Riley and Mr. Stuchbury in 1836*, and were then the oldest Dinosauria in Britain. Since that date the Triassic sandstones of Cheshire, Scotland, and North America have been found to contain the foot-imprints of *Cheirotheria*, and the same formation near Warwick the bones and teeth of remarkable reptiles belonging to the family *Labyrinthodontia*; subsequently it has been discovered that the coal-field of Münster-Appel in Rhenish Bavaria, and that of Saarbruck between Strasburg and Trèves, contain the skulls and bones of several species of air-breathing reptiles which were described by Goldfuss under the generic name *Archegosaurus*. The reptilian remains of the conglomerate, though now not the oldest of their class, still retain their interest for the Palæontologist, as they prove that highly organized Dinosauria lived on Triassic land. I must refer you to the original memoir for a full account of these bones, which enabled its authors to establish two genera for them. The one, *Thecodontosaurus*, has the teeth placed closely together in the jaw-bones. They are sharp, conical, compressed, and have their anterior and posterior borders finely denticulated, and the extremity slightly bent, like the teeth of *Megalosaurus*. *Palæosaurus* has the teeth compressed and pointed likewise; but one of the borders only is denticulated, and the other trenchant. The species are distinguished by the size and form of the teeth. The vertebræ resemble those of *Teleosaurus* in being contracted in the middle, and having their articular surfaces slightly biconcave; and the rest of the bones of the skeleton resemble the forms of the Lacertian type.

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* Trans. Geol. Soc. 2nd series, vol. v. p. 349 (1840).

We know very little of the life of the Trias in the district under consideration, beyond the reptilian remains first noticed here, until we come to the close of this age, when we find upper grey marls of the Keuper overlain by and passing into a series of black shales and limestones known as the *Avicula-contorta* or Rhætic beds, which have a great interest for us, as they comprise the famous Bone-bed of Aust Cliff known to all geologists. The leading fossils are *Avicula contorta*, *Cardium Rhæticum*, *Monotis decussata*, *Pecten Valoniensis*, and the small crustacean *Estheria minuta*. The fishes are *Nemacanthus*, *Saurichthys*, *Hybodus*, *Gyrolepis*, *Sargodon*, and *Ceratodus*, with bones of *Plesiosaurus* and *Ichthyosaurus*. It is the teeth of *Ceratodus*, or horned teeth, that have made Aust Cliff famous; and more than 400 different forms have been described. Mr. C. T. Higgins made the finest collection of these remains, which has been purchased for the Museum, and forms one of its rarest treasures. When these horned teeth, so called from the prominences they exhibit, were first described by Agassiz, the living species of this genus was not known; it is now ascertained that it lives in the Mary, Dawson, and other rivers of Queensland, and is called by the natives "Barramanda." The *Ceratodus* is very nearly allied to the *Lepidosiren*, is cartilaginous, a vegetable-eater, and, like the *Lepidosiren*, lives in muddy creeks; during the hot season it buries itself in the mud, whence it is dug up by the natives, its retreat being discovered by the air-hole through which it breathes; its nostrils are placed in the inside of the roof of the mouth.

A very interesting paper on *Ceratodus Fosteri* (the specimen in the Museum) by Mr. Stoddart, F.G.S., will be found in the 'Proceedings of the Bristol Naturalists' Society,' vol. i. p. 145.

The Lias, which succeeds the *Avicula-contorta* beds, presents a remarkable contrast to them, and shows how much the life-conditions of every age depend on the physical agents that surround it. Two groups of animals appeared in great force in the Liassic Sea—Ammonites and Reptiles.

The Ammonites of the Lower Lias beds (*A. angulatus*, *A. Bucklandi*, *A. Conybeari* and others) attained a large size; and the middle and upper divisions of the same formations were all characterized by different species that marked horizons of life in these divisions. Associated with the Ammonites a large assemblage of other Mollusca are found, as *Gryphæa*, *Lima*, *Unicardium*, *Pholadomya*, *Cardinia*, *Hippopodium*, *Pleurotomaria*, and a profusion of Belemnites and large *Nautili*.

The Reptiles were very large, as you can see by the fine specimens on the walls: *Ichthyosaurus* and *Plesiosaurus* were the dominant forms of this Class; and Pterodactyles with expanded wings performed the part of birds on the dry land of that era; so that the air, the estuary, and the ocean had each separate forms of Reptile life in the Lias age. Another change of conditions introduces us to new forms in the Lower Jurassic sea. A large number of species of Conchifera and Gasteropoda crowd the shelly beds of the Inferior Oolite; and new forms of Ammonites appertaining to groups entirely different from those of the Lias are found in abundance in Dundry Hill. In addition to the Mollusca we find many beautiful forms of Echinodermata, and a large collection of reef-building corals in the upper beds of the hill. Nothing gives us a clearer insight into the fact that all fossil species had a limited life in time than the distribution of the Echinodermata of the Jurassic strata, inasmuch as these animals possess a skeleton of remarkable structure, on which generic and specific characters are well preserved; they form, therefore, an important class of the Invertebrata for the study of the life-history of species in time and space; and the Table of the stratigraphical distribution of the Jurassic Echinoderms which I now exhibit reduces these observations to a practical demonstration.

The Oolitic rocks were formed in a coral sea analogous to that which rolls its waters in the Pacific between 30° on each side of the equator. In the Lower Oolites are four or five Coral-formations superimposed one above another, with intermediate beds of Mollusca. The Middle Oolite is remarkable for the number and extent of its coral reefs, and the Upper Oolite for those found in the Portlandian series.

The Jurassic rocks were accumulated as sediments or shore-deposits under many changes of condition; and the idea of a slowly subsiding bed of the coralline sea gives us, perhaps, the nearest approach to what appears to have prevailed.

The Jurassic waters were studded with coral reefs, extending over an area equal to that of Europe, as they stretch through England diagonally from Yorkshire to Dorsetshire, through France from the coast of Normandy to the shores of the Mediterranean, forming besides a chain winding obliquely through the Ardennes in the north to Charente-Inférieure in the south, including Savoy, the Hautes-Alpes and Basses-Alpes, the Jura Franche-comté, the Jura Chain of Switzerland throughout its entire length from Schaffhausen on the Rhine to Cobourg in Saxony, and along the range of the Swabian Alps and Franconian Jura. Throughout all this widely extended oolitic region coralline strata were accumulating through countless ages by the living energies of Jurassic Polypifera, as all the Madreporic limestone beds in these formations are due to the life-energies of different species of Anthozoa; and were we to venture to estimate the lapse of time occupied in the sedimentation of the coralligenous Oolites by what we know of the life-history of some living species, we should find good reasons for concluding that the Jurassic age must have been one of long duration. It is not the mere coralline structure *per se* that is due to Polyp-life, but the entire mass of Oolitic limestones are the products of the same vital force; for there could be no doubt in the mind of any competent observer who carefully examined such a rock as that in my hand that it was a mass of coral secreted by a Jurassic polyp, and that the Oolitic limestone which surrounds the coral stem is the product of a portion of a wasted reef which had been broken up, ground into mud, and constituted the calcareous paste that had coated particles on the shore, and formed by the roll of the waves the oolitic globules which were afterwards cemented by calcareous waters, and the whole transformed into the rock we call Oolitic limestone; and thus the genesis of the Oolites was due to the vital energies of the myriads of polyps that lived in the Jurassic seas.

The reefs that remain are merely fragments of what had existed; and those that have disappeared furnished the calcareous material out of which the Oolites of subsequent formations have been built up.

I have to thank my old friend Mr. Etheridge for the valuable notes he has supplied on the Mendip Hills (which he knows so well), and to Mr. M'Murtrie for his excellent notes on the Radstock district (which he has so long explored), and to Mr. Stoddart for kindness and assistance in many ways. Without their friendly cooperation it would have been impossible for me to have given so much exact information on the structure of the interesting and complicated region in which we have again assembled.

In these remarks I have carefully avoided any allusion to the origin of species, because Geology suggests no theory of natural causes, and Palæontology affords no support to the hypothesis which seeks by a system of evolution to derive all the varied forms of organic life from preexisting organisms of a lower type. As far as I have been able to read the records of the rocks, I confess I have failed to discover any lineal series among the vast assemblage of extinct species, which might form a basis and lend reliable biological support to such a theory. Instead of a gradation upwards in certain groups and classes of fossil animals, we find, on the contrary, that their first representatives are not the lowest, but often highly organized types of the class to which they belong. This is well illustrated in the Corals, Crinoids, Asteriadæ, Mollusca, and Crustacea of the Silurian age, and which make up the beginnings of life in the Palæozoic period. The fishes of the Old Red Sandstone we have already seen occupy a respectable position among the Pisces; and the Reptiles of the Trias are not the lowest forms of their class, but highly organized Dinosauria. *Ichthyosaurus*, *Plesiosaurus*, *Pterodactylus*, *Teleosaurus*, and *Megalosaurus* stand out in bold relief from the Mesozoic strata as remarkable types of animal life that were specially organized and marvellously adapted to fulfil important conditions of existence in the Reptilian age; they afford, I submit, conclusive evidence of special work of the Great Designing Mind which pervades all creation, organic and inorganic. In a word, Palæontology brings us face to face with the Creator, and shows us plainly how in all that marvellous past there always has existed the most complete and perfect relation between external nature and the structure and duration of the organic forms which gave life and activity to each succeeding age.

Palæontology likewise discloses to our feeble understanding some of those methods by which the Infinite works through natural forces to accomplish and maintain His Creative design, and thereby teaches us that there has been a glorious scheme and a gradual accomplishment of purpose through unmeasured periods of time; but Palæontology affords no solution of the problem of creation, whether of kinds, of matter, or of species of life, beyond this, that although countless ages have rolled away since the denizens of the Silurian beach lived and moved and had their being, the same Biological laws that governed their life, assigned them their position in the world's story, and limited their duration in time and space, are identical with those which are expressed in the morphology and distribution of the countless organisms which live on the earth's surface at the present time; and this fact realizes in a material form the truth and force of those assuring words, that the Great Author of all things, in these His works, is the same yesterday, today, and for ever.

Description of a new Species of Labyrinthodont Amphibia from the Coal at Jarrow Colliery, near Castlecomer, co. Kilkenny. By WILLIAM HELLIER BAILY, *F.L.S., F.G.S., M.R.I.A., Acting Palæontologist to H.M. Geological Survey of Ireland.*

The discovery of the remains of as many as seven genera of vertebrate animals of the Labyrinthodont type, associated with large Ganoid fish (*Rhizodus*, *Gyracanthus*, &c.) and plant-remains (*Lepidodendron* and *Sigillaria*, with a few ferns, *Alethopteris lonchitica*, *Sphenopteris latifolia*, &c.), ten years ago in the coal of Jarrow Colliery, co. Kilkenny, by Mr. W. B. Brownrigg, and their description by Prof. Huxley (see a joint memoir by that gentleman and Prof. E. Perceval Wright, Trans. Royal Irish Acad. vol. xxiv. 1867, pp. 351 &c.) was alluded to by the author.

Since then a much larger example than any of those previously described had been obtained from the same colliery by the Geological Survey of Ireland, and was the subject of the present communication. The occurrence of the genus *Anthracosaurus* amongst the fossils formerly obtained from this colliery had already been indicated by Prof. Huxley; that specimen, however, only consisted of a group of vertebræ and ribs, now in the British Museum collection. This the author had examined, and believed it to be identical with corresponding parts in the fossil now brought before the notice of the Association, and which he had named *Anthracosaurus Edgei*, considering it to be allied to, but not identical with, *A. Russelli*, Huxley, a species from the Lanarkshire coal-field, of which the palatine or under portion of the head, with the teeth, was the only part known. In *A. Edgei* a side view of the entire head is presented to view, triangular in shape, with a rounded snout, showing the large eye-orbits, external nostrils, and series of alveolar cavities. A detached ramus of the jaw, most probably of the same animal, also shows the remains of a dental series, a well-defined articulating extremity, and the division between the dentary and angular bones. Detached teeth near this jaw evidently belonged to it; they were described as conical, slightly curved, pointed, and finely striated, 1¼ inch long by ½ inch in diameter; also other smaller ones, only three eighths of an inch by one eighth and a half. The characteristic sculptured surface of the bone was well preserved on the detached jaw, and observable on several parts of the head. A portion of the body, consisting of displaced vertebræ and ribs, with some larger bones (probably humerus, ilium, and other bones of the fore and hind limbs), were scattered over the slab; the termination of the body and tail was unfortunately deficient.

The bones were not in a very satisfactory state for study. Some of the vertebræ possessed their spinous processes (*neurapophyses*) and exhibited their concave articular surfaces; in others the *centra* only were preserved; these were about an inch long and half an inch in breadth, the spinous processes being from 1½ to 2 inches in height and ¾ inch wide at their upper and widest part. The longest rib measured about 6½ inches with the curve, being ⅜ inch broad, a slight groove traversing its length; the proximal end shows the double articulating portions, *capitulum* and *tuberculum*. In the group of ribs and vertebræ from the same colliery, before alluded to as being in the British Museum, one of the ribs measured 9¼ inches with the curve and ½ inch in breadth, showing it to have belonged to a much larger animal.

The extreme length of the head is about 14 inches, measuring from the snout to the tympanic bone; its height from the lower portion of the under jaw to the supraoccipital is 9½ inches, being in the proportion of two thirds to the length. The total length of the specimen is about 3 feet; this does not, however, represent any thing like that of the entire animal when complete, which must have been at least 6 or 8 feet long.

The condition of the fossil, which is impressed upon two large slabs of anthracite coal (obverse and reverse of the same specimen), is not at all favourable for exact determination, and it is much flattened by pressure.

On the Action of Ice in what is usually termed the Glacial Period.

By the Rev. James Brodie.

It is generally supposed that there was a lengthened period intermediate between the tertiary and the quaternary eras, when a great part of the earth was subjected to extreme cold. This has been called the Glacial Period or Great Ice Age.

The facts adduced in support of these conjectures are:—

Traces of glacier-action have been found in regions which now enjoy a temperate climate;

Boulders, evidently transported by glacial currents from northern regions, are found in temperate localities.

My reply is, that these discoveries prove that in former times there must have been great cold in places which are now comparatively warm; but they do not prove that that cold was contemporaneous over all the quarters where these traces are found. When the climate was cold in one place, there is every reason for supposing that it was warm in others.

Glaciers are rivers of ice; they come down from the mountain-side; but they are fed by the vapours that are principally raised by the action of the sun on the intertropical seas. If the area from which that vapour is raised be diminished, the vapour will be diminished; and if vapour is not supplied, no glacier can be formed.

Glacial currents come from the polar regions; but they would cease if countercurrents from the equator did not bring up water to supply the place of that which they carry away.

It has continued its uninterrupted onward course, the cold gradually increasing in intensity, down to the present day.

On the further Extension of the Rhætic or Penarth Beds in Warwickshire, Leicestershire, Nottinghamshire, Yorkshire, and Cumberland; and on the Occurrence of some supposed Remains of a new Labyrinthodon and a new Radiate therein. By the Rev. P. B. Brodie, *F.G.S.*

The author points out a considerable extension of the Rhætics in Warwickshire, Leicestershire, Nottinghamshire, Lincolnshire, and Yorkshire, and traces of them in Cumberland and Staffordshire. Many sections are described and characteristic fossils given, thus showing that though they appear to thin out north and north-eastwards, yet in all probability they will be detected beneath the Lias in its range from S.W. to N.E. The fine typical sections of Aust, Watchet, Penarth, Westbury, and Wainlode cliffs are alluded to. In this formation near Leicester probable remains of the Labyrinthodon and a new Radiate are for the first time recorded. Thus the British Rhætic series, though greatly inferior both in thickness and abundance and variety of fossils to the much more largely developed rocks of this age in the Austrian Alps, is still a well-defined and highly fossiliferous formation occupying a considerable area and holding an important and independent position; and future researches will no doubt greatly increase our knowledge both of its extent and fossils.

On the Origin of the Red Clay found by the 'Challenger' at great Depths in the Ocean. By Dr. W. B. Carpenter, *F.R.S.*

On the Condition of the Sea-bottom of the North Pacific, as shown by the Soundings recently taken by the U.S. Steamship 'Tuscarora.' By Dr. W. B. Carpenter, *F.R.S.*

On the Northern End of the Bristol Coalfield. By Handel Cossham, *F.G.S.*, Edward Wethered, *F.G.S., and* Walter Saise, *F.G.S.*

Note on the Deposit of Tin-ore at Park of Mines, St. Columb, Cornwall. By Clement Le Neve Foster, *B.A., D.Sc., F.G.S.*

The tin-ore occurs in thin layers, generally 1 or 2 inches thick, interposed between the planes of bedding of the clay-slate, or *killas*, a hardened jointy shale. These layers strike E. & W., and dip north, at an angle of 60° or 70° with the killas. They appear to be lateral offshoots of small north and south veins, and they rarely extend more than a few feet to the E. and W. of them. Sometimes the killas is full of little layers of tinstone for a distance of 100 fathoms from N. to S., 40 fathoms along the dip, and 6 to 10 feet along the strike.

On Moraines as the retaining Walls of Lakes. By Edward Fry, *Q.C.*

The object of this paper is to ask a question.

The origin of many lakes is attributed to terminal moraines of extinct glaciers, which are supposed to act as the retaining walls by which the water is held back to form a lake. Llyn Idwyl is referred to as an illustration of this theory. But all terminal moraines of existing glaciers are cut through to the level of the ground by the streams from the glaciers. The numerous terminal moraines of the Rhone glacier, each cut through by the infant Rhone, were referred to as an illustration of this familiar fact.

For a moraine to act as a retaining wall for water, the breach must be wholly or partially filled up. How has this been done?

Notes on the Variations in Character and Thickness of the Millstone-grit of North Derbyshire and the adjoining parts of Yorkshire, and on the probable manner in which these Changes have been produced. By A. H. Green, *M.A., F.G.S.*

The Millstone-grit of the district treated of was subdivided as follows:—

Top.
(3) Rough Rock.
(2) Middle Grits.
(1) Kinder-Scout Grits.
Bottom.

(3) is a bed which, in spite of some local variations, may be fairly spoken of as singularly constant in character and thickness.

(2) is a remarkably changeable group. In Derbyshire its most striking member is the Grit of Chatsworth (the Third Grit of the Geological Survey); this was shown to be a bed of only local occurrence, thinning away and disappearing entirely to the north. The beds above the Chatsworth Grit in Derbyshire which are called Second Grits by the Geological Survey, and the rocks in South Yorkshire which are called Third Grits by the Geological Survey, were shown to be in a general way the equivalents of one another, though, on account of the numerous changes that are met with in passing from place to place, no correlation of individual beds was possible.

(1) is a group less changeable as a whole than the Middle Grits, but liable to many local variations. One very striking case of the sudden thinning away of a great mass of Grit and Conglomerate that forms its base in Derbyshire was described. To account for the variations spoken of, it was pointed out that wedge-shaped masses of sandstone have been, sometimes *banks* formed in shallow water and tailing out in the direction in which the water deepened, sometimes *heaps* piled up by the action of opposing currents. But it seemed that in the present case the occurrence of lenticular masses of sandstone could in several instances be best explained by supposing that the floor on which these beds were deposited was very uneven and full of hollows, and that the great cakes of sandstone had been formed by the filling-up of these depressions by drifted sandy sediment.

Notes on Carboniferous Encrinites from Clifton and from Lancashire. By J. G. Grenfell, *B.A., F.G.S.*

The author exhibited and described a series of *Poteriocrinus plicatus* from the base of the Carboniferous limestone in the gorge of the Avon. The new facts brought to light by these specimens are the anal plates, the arms which bifurcate four times, giving eighty rays, the stem and its side arms, and a very remarkable proboscis exhibiting a structure hitherto unknown amongst the Crinoids. One of these is 4¼ inches long by ¾ inch wide, and is composed of long narrow plates arranged in five horizontal rows with longitudinal and transverse ridges.

The total number of plates is upwards of 1300.

A new species of *Poteriocrinus* was then described, *P. rugosus* (Grenfell), found in the Lower Limestone Shales, Clifton, which resembles *P. pentagonus* and *P. longidactylus* (Austin), but is distinguished by the depression of the angles and lateral articulations of the body-plates, and by the surface of the body being rough and that of the arms strongly wrinkled.

A specimen of *Rhodocrinus verus* from Clifton showed that the rays of this species, hitherto unknown, were twenty in number and closely tentaculated. Miller's figures of this species include a distinct Silurian fossil, for which Phillips and De Koninck would retain the name *R. verus.* Since, however, Miller's detailed drawing of the species agrees with the specimen exhibited, it was urged that this latter has the best claim to the name.

Rhodocrinus verisimilis (Grenfell), a new species from Clifton, was described. It resembles *R. verus*, but differs in the arms being short, wide, and flat, and in the rays being 40.

The author then showed that Phillips's generic description of *Gilbertsocrinus* was inaccurate in the shape of the scapulæ and first intercostal; but he argued that the genus should not be confounded with *Rhodocrinus*, as had been done of late years, being clearly distinguished by the form of the brachials and by the presence of orifices opening into the perforations in the arms. He suggested that these openings are not ovarian, but for the purpose of admitting water into the interior.

Gilbertsocrinus may be defined thus:—

Basals 5; subradials 5; radials 3; brachials several, irregular; the second brachial channelled at top, and leading into an orifice which communicates with the perforation in the arms; axillary plates well developed; arms round, and generally set at right angles to the body; body-plates generally tuberculate.

A new species of *Gilbertsocrinus* from Lancashire was described, *G. Konincki* (Grenfell). It is distinguished from all except *G. simplex* (Portlock) by five prominent tubercles round the base. From that species it differs in shape and size, in the narrowness of the subradials, and the presence of tubercles on the body-plates.

On the Influx and Stranding of Icebergs during the so-called Glacial Epoch, and a suggestion of the possible cause of the Oscillation of the Level of Land and Water to which that Influx may be due. By John Gunn.

The author repeated his previously propounded views, that an influx of icebergs was due to the increased area and depth of the sea in the northern hemisphere, by which the perpetual snow-line was altered, and consequently masses of ice and glaciers were disengaged and set floating southward.

When the sea was of sufficient depth the icebergs would float over the land, and their passage would be marked by boulders let fall, as was the case in the Chalk, in which they are occasionally found imbedded; but when the sea was shallow they would be stranded, and the effects described by Mr. Gunn would be produced, as in Ireland and the east of England.

These phenomena were, he represented, distinct from glaciers formed on mountainous districts, as in Wales and the north of England, which would be indicative of cold; whereas the increased area of the sea would indicate a milder climate, except so far as it would be affected by the influx of ice.

Mr. Gunn conjectured that as no adequate cause had been assigned for the alternate increase of water in the two hemispheres, it might possibly be due to the motion of the solar system in space, which Sir John Herschel had treated as a useless speculation, but to which Otto Struve and other astronomers had directed their attention, and had endeavoured to demonstrate the velocity and direction of. They had not, however, at present been able to ascertain whether the sun with its cortége of planets revolved around any and what centre.

Here, therefore, was an unknown quantity; and since all other movements are inadequate to produce all the required results, he ventured to hint that they might be due to this. He referred to the possibility that the tides might be affected by the relative position of the sun to the earth, which might undergo a change during the enormous extent of the revolution of the solar system. At any rate it appeared to him that no positive conclusion could be arrived at until this was settled.

On the Occurrence of Rhætic Beds near Leicester.

By William J. Harrison.

The Spinney Hills are a low range forming the eastern boundary of the town of Leicester and of the Soar valley. They are composed of red and blue Keuper marls containing selenite, salt-crystals, and a massive nodular band of gypsum.

At the northern extremity the range is capped by the Rhætic beds, which are cut off from the Lias on the east by the valley of a little stream, the Willo brook. A vertical section of from 30 to 40 feet is obtained in brick-pits, whilst a boring of coal in an adjacent field has reached a depth of 600 feet, and is still in the Keuper marls and clays.

The floor of the brick-pits is of red Keuper marl, resting on which is a thick bed of grey marl, about 16 feet, with insect and fish remains, selenite and pseudomorphic salt-crystals, pittings as of rain-drops, &c. On its uneven upper surface rests the bone-bed, 2 inches thick, containing rolled Saurian bones, vertebræ, and teeth of *Ichthyosaurus*, ribs of *Plesiosaurus*, spines of *Nemacanthus monilifer* and *Hybodus minor*, teeth, scales, &c. of *Hybodus*, *Laricthys apicalis*, *Ceratodus*, &c. Coprolites and large quartzose pebbles are numerous.

Above this come 5 feet of black shales, containing a new Starfish, *Ophiolepis damesii*, and *Avicula contorta*, *Cardium rhæticum*, *Axinus cloacinus*, &c.; then about 4 feet of light-coloured shales with the same fossils; and the whole is capped by a bed of rubbly limestone, 3 inches thick, containing casts of *Estheria minuta*. The beds have a slight dip to the S.E.

Undulations of the Chalk in the North of France, and their probable existence under the Straits of Dover. *By* Professor E. Hébert.

I showed at the Brighton Meeting that the beds of Chalk in the north of France are folded so as to form five anticlinal axes having a S.E. and N.W. direction, viz.

the axis of the Perche,
" " Seine,
" " Bray,
" " Bresle,
" " Artois.

On the present occasion I am about to prove that there is another series of folds at right angles to the former, that is to say having a S.W. and N.E. direction.

The mode of demonstration is very simple and rigorous. I take for example a well-known bed, such as the *Chloritic Marl*, and observe its altitude at various points.

Taking, for example, the region between Fécamp and Paris, which belongs to the S.E. and N.W. anticlinal axis of the Seine, we see the Chloritic Marl at Fécamp at the level of the sea; the beds rise to the S.E., and the same bed (near Montheville, 10 kilometres off) reaches 270 feet. Then they sink, so that the surface is soon formed of the *Micraster cor-testudinarium* beds, which are separated more than 200 feet from the Chloritic Marl. They afterwards rise again, and the Chloritic Marl once more attains a height of 260 feet at Pavilly. It next descends by 470 feet at least, rises again to 150 feet at Rouen; and the base of the Chalk with *M. cor-testudinarium* reaches the height of nearly 500 feet. Again a dip takes place between Rouen and Vernon, this time of 340 feet; then at Pressagny, near Vernon, the Chloritic Marl appears at 169 feet; and finally there is a regular dip towards Paris, where the Chloritic Marl is at about 1500 feet below the level of the sea.

Thus the region between Fécamp and Vernon presents four undulations (Fécamp, Pavilly, Rouen, and Vernon), the extent of which ranges between 400 and 500 feet.

By a similar method I find that the region comprised between Tréport and Compiègne (the anticlinal axis of the Bresle) presents three bosses, the first having its summit at sea to the N.W. of Tréport, the second at Aumale, the third at Breteuil.

The axes of the Bray and of the Boulonnais present similar undulations. Moreover it is easy to observe that these various bosses are connected among themselves; thus the centre of the Bray axis is precisely on the line which runs from Rouen to Aumale, and this line, prolonged to the north-east, passes by Picquigny-s.-Somme, where is a rising of the Chalk, crosses at Arras the axis of Artois, and from this point is directed towards the ancient rocks which extend from Douai to Tournay.

Here is then a S.W. and N.E. fold of a well-marked character, and the extent of which is recognized from Rouen into Artois.

The Vernon boss is the point whence starts another fold, parallel to the preceding one. This fold traverses the Bray near Ville-en-Bray; it then passes at Breteuil, where a very distinct boss is to be seen.

These two folds are separated by a very distinct synclinal depression, which is anterior to the *Bel. mucronata* chalk, which at the north, near Moreuil and Hardivilliers, have only been deposited in the depression and not on the rise.

A third parallel fold extends from Mentheville, near Fécamp, to Tréport; to the north-east it passes near Lillers, where the Devonian crops out; at Dieppe this fold has caused a fault of about 250 feet. All the Boulonnais is to the N.W. of this line, and the beds dip to the sea. The Gault descends more than 330 feet from Fiennes to Wissant.

But this movement of depression does not continue, and the strike of the beds, which can be perfectly followed at low water, indicates a gradual rise. This strike makes an angle of 38° to 40° with the coast-line (Chelloneix). The beds get further off to the north; but as we find them again exactly the same at Dover, they must necessarily curve round towards the west; and this can only be by the effect of an undulation similar to the last.

It is a legitimate inference to draw that the lie of the beds is the same under the channel as on the coast; and direct observation brings us to the same conclusion, viz. that the Cretaceous beds are raised in the form of an anticlinal axis in the middle of the Straits. Most certainly, starting from any point of the coast between Blanc Nez and Calais, so as to proceed to Dover in a straight line, it will be impossible to keep in the same horizon of Chalk Marl, or Chalk without flints, even if this bed were 400 feet thick. An undulation or boss some 400 to 500 feet must be expected.

We should therefore have here, in consequence of the preceding facts and arguments, a fourth axis (S.W. and N.E), *l'axe de la Manche.*

The existence of this axis was announced in 1846 by D'Archiac, who reasoned from very different data. Every thing concurs to prove its reality.

It will be noticed that the extent of these undulations, which always bring the Upper Greensand to the surface in the north of France, increases constantly on approaching the sea.

At Fécamp the Upper Greensand, which is here quite sandy, crops out at more than 270 feet; at Aumale it reaches 400 feet; there is therefore serious cause for thinking that a tunnel carried in a straight line would go through not only the Upper Greensand, but also beds of older age.

The two systems of folds which I have described both bring about important faults, from 260 to 400 feet in throw. The first parallel to the axis of the Boulonnais and Weald is not likely, in my opinion, to have produced any great fault in its line of trend in the beds to be cut through by the tunnel. As to the second, there would be nothing surprising if it should have caused a line of fracture parallel to the *Channel axis*; but hitherto no evidence has been forthcoming on this point.

It follows from what I have said that if the tunnel is bored in the *Chalk Marl* or *the Chalk without Flints*, or even proximately above this layer, it will leave not only this bed, but also the *Chalk Marl* and *Green Chalk*, and meet Upper Greensand, the sandy base of which, lying on the clay of Gault, may, or rather must, contain a sheet of water.

A means of avoiding the Upper Greensand would be to take a northerly direction towards Calais, and to enter first the Chalk with Flints and then to go down into the Chalk Marl. But this Chalk with Flints contains permeable beds; so that the boring made at Calais in 1844 tapped at 530 feet a feeder of brackish water.

In my opinion these permeable bands are beds of hard limestone pierced by holes such as I have frequently observed in the Chalk. It is to one of these bands that Mr. Whitaker has given the name of *Chalk Rock*. I do not say that these beds are always permeable, but that they may be so. I believe that it is they which feed the Artesian wells of Artois.

Now there is one of these beds at the top of the Chalk with *Ammonites Mantelli* and *Ammonites rotomagensis* (Grey Chalk); and there is usually one, sometimes two or three, at the top of the Chalk with few flints. Above that horizon come the *Holaster planus* Chalk-beds of Dover, then those with *Mic. cor-testudinarium* of the base of the southern cliff of St. Margaret; all these beds are generally hard, fissured; yet they will occasion less dangers than the base of the Upper Greensand, and their permeableness may be but accidental.

Such are the data which studies carried on during more than fifteen years enable me to bring forward. Their application to engineering does not come within my province; I leave that entirely to the eminent man who is carrying out this great work, and who I hope will master all obstacles.

On the Geology of New Zealand. By Dr. J. Hector, *F.R.S.*

On some Areas where the Cambrian and Silurian Rocks occur as Conformable Series. By Henry Hicks, *F.G.S.*

The author stated that of late years it has been generally supposed that there was strong evidence in many Welsh sections of the presence of several important breaks in the succession in these rocks, and that the series forming these formations were not deposited over an area becoming gradually depressed, the usual idea being that the area was at one time under water and at another dry land. That this was really the case over limited areas he was not at present prepared to deny; but he thought the evidence of this was as yet imperfect. In other cases, however, he was prepared to contest this view, and, amongst other sections, mentioned the following as showing conclusively that there was not the slightest evidence of the presence of an unconformity.

In Pembrokeshire the succession from the Cambrian to the top of the Llandovery rocks is a perfectly continuous one; and there are no breaks seen anywhere but such as are produced by faults.

In the neighbourhood of Llandovery, the Caradoc, Lower Llandovery, Upper Llandovery, Wenlock, and Ludlow beds are seen resting quite conformably upon each other.

In parts of Shropshire, the Caradoc, Lower Llandovery, Upper Llandovery, Wenlock, and Ludlow are also seen, and there they also appear to be conformable; in the neighbourhood of Cornwen, in Merionethshire, the sections also appear to show a regular succession from the Caradoc through the Tarannon shales to the Derbyshire slates, flags, and grits.

He therefore looked upon these areas as portions of one great and gradually subsiding area, which remained continually under water, and received deposits uninterruptedly from the commencement of the Cambrian to the close of the Silurian epochs. He believed that this was the case over the whole European area where not greatly disturbed by volcanic forces.

On the Distribution of the Graptolites in the Lower Ludlow Rocks near Ludlow. By John Hopkinson, *F.L.S., F.G.S.*

The author first drew attention to the special interest attaching to the Ludlow rocks, in connexion with investigations on the vertical distribution of the Graptolites, as being the formation in which they apparently die out.

The Rhabdophora, or true Graptolites, which, with the Cladophora, or dendroid forms, we find in infinite variety when they first appear in the Arenig rocks, genera the most complex coming in simultaneously with simpler forms, were stated to be represented in the Lower Ludlow rocks by but a single genus, and that the simplest, *Monograptus*—and the Cladophora also by one genus only, *Ptilograptus.*

A list of the Graptolites of the Ludlow rocks, given in a former communication to the British Association (1873), was then alluded to*, and the main conclusions as to the distribution in these rocks near Ludlow of the species enumerated, arrived at in the course of a few days spent at Leintwardine immediately before the opening of the present Meeting, were given.

It was shown that several species of *Monograptus* abound in the lowest beds of the Lower Ludlow, when these lowest beds do not, as they do near Stokesay, form a limestone divided from the Wenlock Limestone by a few feet of shales; that some of these pass up, and a few others come in, a little higher in the series, all in soft calcareous sandy shales, with here and there limestone nodules and bands of limestone; and that when a decided change in the strata takes place, indicating in some places, by more siliceous and gritty beds, comparatively shallow water deposits, and in others, by excessively hard fine-grained limestones, a deeper sea, a decided change in the Graptolite fauna occurs—the gritty beds containing in myriads a single new species, *Monograptus leintwardensis*, and the indurated limestone alone containing the few species of the Cladophora, belonging to the genus *Ptilograptus*, which have yet been detected. *Monograptus colonus* (a form passing up from the lowest Llandovery beds) appeared to be the only species which survived these physical changes, it having alone been seen in the softer beds high in the Lower Ludlow, and passing up from these into the harder calcareous shales, which in some places immediately underlie the Aymestry Limestone, when this is at the summit of the Lower Ludlow, and again passing up into this limestone bed, in which it seems finally to disappear.

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* Rep. Brit. Assoc. for 1873, Trans. Sections, p. 83.

The author considered this Aymestry Limestone to form a portion only of the Lower Ludlow rocks, not being constantly present, and sometimes having beds of Lower Ludlow shales of considerable thickness between its layers; and concluded by showing the dependence of the fossil fauna and flora of these rocks on the physical conditions of the Lower Ludlow seas, the fossils frequently being only locally distributed, and varying slightly in their horizons according to the nature of the sediment deposited, the Graptolites especially being influenced by these changes, to which their final extinction, or at least their dispersion from the area under consideration, was considered to have been most probably due.

To the list previously given a single species only, *Monograptus Roemeri*, Barrande, occurring in the lowest beds of the Lower Ludlow, is added by these recent researches.

Notes on the Classification of the Sedimentary Rocks. By T. McK. Hughes, *M.A., F.S.A., F.G.S., Woodwardian Professor of Geology, Cambridge.*

Prof. Hughes, in advocating a revision of the classification of the sedimentary rocks, pointed out:—

(1) That, although the accumulation of rock-material may have been going on somewhere throughout the whole of the periods with which geologists have to do, still that deposition has been locally interrupted many times;

(2) That the whole evidence had to be considered in each case, as it was a matter of every-day observation that trifling geographical changes might produce considerable alteration not only in the character of the sediment, but also in the fauna and flora of a given area; and small local irregularities, due for instance to volcanic action, might produce phenomena which alone would be taken for an unconformity, implying a long interruption of deposit;

(3) That denudation proves a lapse of time somewhat commensurate with the deposition of a similar thickness of material to that denuded.

Bearing these principles in mind, he observed that the great divisions should be drawn where it can be shown there was the greatest and longest interruption in the continuity of conditions, the minor subdivisions being founded upon more rapidly varying circumstances, which often produce even greater difference in lithological character and fossil contents.

He pointed out that our present classification was very inconsistent—some of the breaks within the Primary, for example, being far more important than that between the Primary and Secondary rocks themselves.

He proposed the following classification, read in ascending order:—

1st Epoch.	*Laurentian.*	*Pre-Cambrian.*
2nd „	*Gap.*	
3rd „	*Labrador Series.*	
4th „	*Gap.*	
5th „	*Huronian?*	

The Huronian he felt to be not quite well defined, but thought it probable that a group would be made out between the Labrador series, or Upper Laurentian, and the Cambrian. He considered that the attempt to identify the subdivisions of the pre-Cambrian rocks in distant countries (Britain and America for instance) was premature. Calling attention to the two unconformable groups which Dr. Hicks had made out at St. David's, he felt satisfied that the Cambrian was unconformable to the upper as well as to the lower, and stated that he had himself found fragments of the hornstones, *i. e.* the Upper pre-Cambrian group, in the conglomerates at the base of the Cambrian. The oldest rocks of N.W. Scotland, of the Malvern Hills, and of Scandinavia, he thought could at present only be safely called pre-Cambrian.

6th Epoch. Gap between Huronian and Cambrian.—Since we have in Britain certainly two, and in America probably three series of deposits before the Cambrian, and the Cambrian may rest on any one of them, it is impossible to estimate the duration of the period between the Cambrian and the newest of the pre-Cambrian rocks.

7th Epoch. Cambrian.—He referred especially to the labours of Dr. Hicks, and thought that there were no hard and fast lines of demarcation between different subdivisions of the Lower and Middle Cambrian, but only zones of life, and that the boundary-lines between the portions of the series in which these zones of life occurred were continually being shifted. Sometimes, where a change in the sediment happened to come between two zones, this was seized upon as marking a convenient place to draw a line. Such a boundary was that offered by the Garth Grit, which comes between the zone of *Angelina Sedgwickii* and that of *Æglina binodosa.* No life zone older than this last appears to have been yet made out in the Lake-district. This grit is not a conglomerate formed of fragments of the underlying rock, but is made up almost entirely of quartz-pebbles, small and well worn, as if derived from a distance. A precisely similar grit occurs associated with somewhat similar slate low down in the green slates and porphyry in Chapel-le-Dale on the S.E. border of the Lake-district, probably not very far above the horizon of the Garth Grit. It is like the grit which occurs frequently in South Wales in the Caradoc beds, in the Denbigh Grits in North Wales, and in the Lake-district in the Coniston Grits, and in all these cases is known to be far above the base in a conformable series.

A great part of the series above this horizon is, in the Lake-district and in North Wales, made up of volcanic ejectamenta. In North Wales the ash and lava seem to have been deposited in the sea and modified by its action; while in the intervals between the periods of volcanic activity various forms of marine life lived on the muddy bottom, which enable us to correlate the beds with the Bala series. In the Lake-district the sea seems to have been filled up by the immense quantity of material thrown out, and much of the accumulation is supposed to have been subaerial. In both districts volcanic activity seems to have ceased, while the fauna of the Bala Limestone still inhabited the area; and subsidence went on while the Bala and Hirnant Limestones, with a great mass of interbedded and overlying flags, were deposited in North Wales; and in the Lake-district the corresponding deposits, viz. the Coniston Limestone, Fairy-Gill Shales and Ash-Gill Flags (=Lower Coniston Flags), were formed. In South Wales and the western borders of England only a few ash-like beds suggest the not distant line of volcanic outbursts. Scotland, Scandinavia, Bohemia, and America yield a series which, if not in detail, can in a general way be correlated with these. The fact that the Lake-district and North Wales were during this period the seat of old volcanoes, will partly explain the difficulty that was experienced by Prof. Sedgwick and Sir Roderick Murchison in identifying the corresponding beds in the two areas independently examined by them; and the sudden ending of the volcanic deposits may probably account for the local apparent irregularity of the Coniston or Bala Limestone on the underlying series, which induced Professor Sedgwick to make that limestone the base of his upper subdivision, and which has recently been urged as proofs of an unconformity by Mr. Aveline. Except in connexion with the volcanic deposits, no break has been proved from the conglomerates which form the base of the Harlech group to the top of the Bala series.

8th Epoch. The Gap between the Cambrian and Silurian.—This he thought not strongly marked, and certainly not to be drawn between the Upper and Lower

Llandovery. He criticised the palæontological and other evidence upon which this division had been made, and protested against the introduction of the name Llandovery Rocks instead of May-Hill Sandstone, under which it was first described by Prof. Sedgwick. In the Lake-district and in North Wales in every open section there was an apparent conformity, though the overlap of the Graptolitic mudstone, from the Coniston Limestone of Windermere to the Ash-Gill Flags of Coniston, seemed to suggest an unconformity. The May-Hill Sandstone, thinning out to the north and creeping over the edges of the Cambrian rocks and along the ancient mountain-range of the Malvern and Longmynd, rests on the oldest parts of the Cambrian and even on the pre-Cambrian. Still this cannot be said to represent the previous denudation of the whole thickness of the Cambrian rocks, as they themselves thin out against the old Malvern ridge; so that this epoch would appear to have been characterized in the typical regions by the upheaval of some mountain-chains and irregular movements in large adjoining areas.

9th Epoch. Silurian.—This series he thought commenced with the base of the May-Hill Sandstone (*i. e.* at the bottom of the Lower Llandovery, with some corrections of boundary). There was a very considerable change in the forms of life, and this was conspicuous even where the stratigraphical discordance was not well marked. There was little difference of opinion as to the grouping of beds, except at the commencement and close of the period. Conglomerates mark the base at Austwick and Sedbergh, on the western borders of the Lake country, accompanied by a change in the character and colour of the sediment and of the organic remains. The boundary can be traced through the Lake-district proper, and in North Wales by the same change in the fossils and the sediment, but there is no conglomerate. In South Wales a conglomerate frequently marks the base; but the group of fossils that comes on first is very different, and seems to suggest an earlier submergence of the southern area.

Passing over the Wenlock and Ludlow, the next difficulty is in drawing the upper boundary. This he would take at the top of the red shales and marls of the river Sawdde and the country east of Horeb Chapel in South Wales; for there is no evidence of a break there or anywhere else between the tilestones and the red shales; and where fossils have been found, as at Ledbury, in the red shales they are common Ludlow forms.

The author pointed out, by reference to original and published sections by Prof. Sedgwick, that the views he now advocated as to the classification of the Cambrian rocks and the position of the boundary-line between them and the Silurian were exactly those of Prof. Sedgwick. He further showed, by comparison of the map and sections of Murchison with those of the Survey and later authors, that Murchison had not, in 1839, correctly placed any one of the beds about which he later came into collision with Sedgwick; that the Caradoc of Murchison's sections, supposed to rest on the Llandeilo Flags south of Llandeilo, was May-Hill Sandstone or Wenlock; that the Cambrian rocks, supposed by Murchison to crop out from below the Llandeilo Flags, were Caradoc and newer beds overlying it; that the supposed base of the Llandeilo Flags was in fact the top. He further stated that when these errors were corrected there was no acknowledgment of the approach made in the new editions to the original classification of Sedgwick; that the latest change had carried the base of the Silurian below the unconformities in the Cambrian rocks given in vol. iii. of the 'Memoirs of the Geological Survey,' and had left it where he thought no one would now venture to suggest there was any palæontological or stratigraphical break. As this must be changed, and the unconformities above mentioned would, he thought, be certainly abolished before long, he asked whether for justice and consistency we should not, in adopting Prof. Sedgwick's classification, adopt his nomenclature also.

10th Epoch. The Gap between the Silurian and Carboniferous.—This he considered one of the two most strongly marked gaps (except, possibly, some pre-Cambrian intervals) in all the geologic series. In the north of England the Cambrian and Silurian rocks were folded and denuded down to the Skiddaw Slates: strata to the thickness of at least five or six miles were removed. In the north-west of Wales a similar denudation seems to have been going on; but as we turn to the east we find, along the Vale of Clwyd for instance, that there was not such great contortion and denudation previous to the deposition of the basement-bed of the Carboniferous rocks. The patchy sedimentary base, consisting of sands and conglomerate, rests on the Denbigh grits and flags. Skipping the region of mid Wales, we find in South Wales still less pre-Carboniferous crumpling and denudation. As pointed out above, higher beds belonging to the Silurian series are left than any seen further north; and the sedimentary base of the Carboniferous is thicker. Still further south (in Devonshire &c.), though the actual base is nowhere seen, we have the sedimentary series more strongly developed; and the early type of Devonian fossils agrees with the idea that the Devonian area went down first at the commencement of the Carboniferous epoch.

11*th Epoch. Carboniferous.*—In accordance with the above view of the pre-Carboniferous geographical changes, the author, while disagreeing with Prof. Jukes in his interpretation of the stratigraphical structure of Devonshire, still goes with him in bracketing the Devonian with the Carboniferous, and would refer to the same age most of the Old Red of Scotland, while a great portion of the Old Red of South Wales he would group with the Silurian. Running over the principal subdivisions of the Carboniferous, and noticing the occurrence of coal-seams at lower and lower horizons as we proceed from S. to N., the author next drew attention to the large masses of rock of Carboniferous age which had been so deeply stained from the overlying New Red that they had been grouped with that formation; and pointed out that as we approach the newest known beds of Carboniferous age, we find indications of the commencement of earth movements in the local irregularities in the sequence of the uppermost Coal-measures.

12*th Epoch. The Interval between the Carboniferous and New Red.*—This he considered the second most important gap in the geologic series. The geographical changes which occurred in it were the hardening and upheaval of the whole of the Carboniferous (and how much besides we have not evidence to show), the carving-out of these rocks into hill and valley, and the development of a flora and fauna differing considerably from those preserved in the Carboniferous rocks. As the base of the New Red rests on the edges of rocks from one to four miles in thickness, this epoch must have been of very long duration.

13*th Epoch. New Red and Jurassic.*—This epoch, like the Carboniferous, commenced with the variable deposits accumulated along the shores and in the lakes and valleys of an irregular continent unequally submerged. They consist of conglomerates, sandstones, and mudstones, and, like those at the base of the Carboniferous, generally of a bright red colour. The red stain penetrates deep into the underlying rocks, the surface of which often shows evidence of subaerial weathering. What wonder that, as headlands disappeared, as barriers went down, as depressions got silted up, there should be irregularities of all kinds observable between successive deposits—such, for instance, as that at the base of the Upper Magnesian Limestone in places, or that between the Lower and Upper New Red, or that between the Bunter and Keuper. (He dropped the word Permian, as it was only a new name given by Murchison to what had been previously correctly described by Sedgwick as Lower New Red.)

These rocks passed up through the Rhætic and Lias into the Oolitic series, at the close of which, as in every other case, we have a hint of the approaching changes. Probably we shall some day have sufficient data to speculate on the limit to which it is possible that continuous deposition can go on uninterruptedly in the same area. However that may be, the further on we get in geologic history the more clear does the evidence become that, as great waves of depression pass across an area, sometimes the accumulation of sediment keeps pace with it, and leaves deposits which show that the hollows had been filled and lagoons and estuaries had taken their place by the time the trough of depression had passed and the wave of upheaval had succeeded. Towards the close of the Jurassic epoch, at any rate, we have the Purbeck freshwater beds, and later the Weald estuary, where we know there had been hundreds, and probably thousands of feet of continuous marine deposits.

The author then considered briefly the gaps which occurred at the base of the Neocomian and of the Cretaceous, and the intervals of which we have evidence at the base of the Eocene and of the Miocene, but reserved the fuller investigation of these points for a future occasion.

Observations on the Discovery, by Count Abbot Castracane, of Diatomaceæ in Coal from Lancashire and other places[*]. *By* Prof. EDWARD HULL, *F.R.S.*

The author considered this discovery of so much interest and importance as to entitle it to the special notice of the Section, and particularly for the light it throws on the mode of formation of Carboniferous coal. Diatoms had been observed by Count Castracane in specimens of coal from Liverpool, Newcastle, Scotland, and St. Etienne; and in these, after repeated observations in which every precaution had been taken to guard against deception, examples had been found in greater or less numbers. The species observed are identified by Count Castracane with existing forms, and, with the exception of three marine genera from the coal of Lancashire, were all of freshwater origin. The results appeared to the author to corroborate the views of those who consider that Carboniferous coal had its source in the decay of forests of plants, which grew with their roots and parts of their stems under stagnant lagoons, into which the waters of the ocean occasionally found access.

The Drifting-power of Tidal Currents and that of Wind-waves[†]. *By* G. HENRY KINAHAN, *M.R.I.A. &c.*

The author referred to the Report on Waves by J. Scott Russell (Brit. Assoc. Reports, vol. xiii, 1844, p. 311), which he considered ought to have decided the relative merits of the tidal currents and wind-waves. This, however, seems not to be the case, judging from the recent paper on the Chesil bank, Dorsetshire, read by Professor Prestwich before the Institution of Civil Engineers (February 2nd, 1875), and the discussion that followed the reading of it.

After mentioning what can be learned from Scott Russell's Report, the author gives the general conclusions he arrived at, after many years of the study of the drifting-power of the tidal currents and that of wind-waves on the coast of Ireland; and to illustrate these general conclusions, a detailed description was given of that portion of the coast of Ireland (part of Wicklow, Wexford, and Waterford) contained in the Admiralty charts (Ireland, sheets xiv. & xv.), as this coast was minutely examined and the results tabulated.

The memoir concluded as follows. The information gathered on this portion of the coast of Ireland goes to prove the following:—

1st. The driftage due to the incoming tidal currents is always, during its progress, going on in deep water, and more or less in the shallow water.

2nd. The driftage due to wind-waves only occurs during gales, and even then is only due to the waves that break on the shores.

3rd. To prevent the tidal driftage, groins or piers should be erected; and if the pier is to form a harbour, transverse groins should run out from it to stop the back-wash generated by the piers; for otherwise this back-wash would carry the driftage seaward to be sucked round the pier into the harbour.

4th. As the wind-wave driftage occurs during gales, and then only on the shore-line, it might be prevented from silting up a harbour or damaging the shipping in it by placing a breakwater across the direction from which the prevailing storms come. If such a breakwater were a fixed one, built of stone or some such, it must more or less affect the tidal driftage, and probably would help to silt up the harbour; but if it were floating, it would break the wind-waves in deep water, thus destroying their drifting-powers, while there would be no impediment to interfere with the tidal driftage.

On the Limits of the Yoredale Series in the North of England. *By* G. A. LEBOUR, *F.G.S. &c.*

The author urged that the Great Whin-Sill, being an intrusive sheet of trap which shifted its horizon frequently in Northumberland, was worthless as a base-line to the Yoredale series; that north of the Pennine escarpment the Scar limestone series lost its distinct character and became quite indistinguishable from the Yoredales, either stratigraphically or palæontologically; but that the entire set of beds between the Millstone-grit and the Tuedians in Northumberland represented the entire Carboniferous Limestone series of the Midlands and Belgium, and not only, as Prof. de Koninck had lately stated, the Upper Division, or *Calcaire de Visé*. The name "Bernician series" was proposed for the whole series having a Yoredale *facies* in Northumberland[*].

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[*] Atti dell' Accad. Pont. de' Nuovi Lincei. Roma, 1874. A translation of the memoir, by Miss Littledale, of Dublin, appears in the Geol. Mag., Sept. 1875.

[†] See 'Royal Irish Academy Proceedings,' 1875-76.

On the Geological meaning of the term "River-basin," and the desirability of substituting "Drainage-area." *By* D. MACKINTOSH, *F.G.S.*

The author believes that though field-geologists understand the meaning of the word "river-basin," it is not only liable to convey a false impression, but has actually induced many geographers to represent watersheds as almost invariably running along the higher ground; and, as a consequence, mountain-chains are represented as if they ran continuously along the lines of watershed or water-parting. In most maps, so-called river-basins are represented as if they were really basin-shaped; but the author contends that there is scarcely such a thing in nature as a river possessed of an uninterrupted basin extending from end to end of its course; that in mountainous countries rivers either flow through ruined mountain-domes, or what might be called inverted river-basins, or they traverse with equal indifference a series of basins and connecting narrow gorges. These basins are generally oblong; and in most instances the rivers cross them, not in the direction of their length, but obliquely. He describes the ruined dome through which the Dee flows in North Wales, and shows that the majority of the highest eminences are situated not on the sides, but towards the centre of this so-called river-basin. He also describes the miscalled basins of the Wye in South Wales, the Tamar, and the Bristol Avon. After recommending the word "drainage-area" as a substitute for "river-basin," he concludes with an explanation of how mountains constituting "lines of weakness" were either worn down into valleys or merely sawn asunder by marine denudation, so as to leave a series of narrow gorges through which rivers found their way to the sea.

On the Origin of two polished and sharpened Stones from Cefn Cave. *By* D. MACKINTOSH, *F.G.S.*

The author entered particularly into a description and explanation of the peculiarities of form and polish presented by two fragments of limestone found in the part of Cefn Cave where sand and sea-shells might still be seen clinging to the rocky wall. One of the stones was axe-shaped, with a very sharp edge, and an intensely polished though only partially smoothed surface. Many reasons were stated for arriving at the conclusion that the stones were first in the state of rocky projections, roughly shaped by fresh water charged with carbonic acid gas—that the subsequently polished surfaces and sharpened edges could not have resulted from human agency, as they exhibited no indications of design, and could never have answered any human purpose—and that they were merely an extreme or exceptional result of some kind of natural agency. The author endeavoured to show that the polished surfaces could not have been caused by the rubbing of cave mammalia, as they occurred on both sides, and ran very nearly all round the specimens. In discussing the natural causes by which the stones were finally shaped and polished, he showed that fresh water or a stream of water running only in one direction could not have been the agent, and that the only adequate explanation was to be found in the to-and-fro, recurving, insinuating, and powerful action of sea-waves. The author went on to show that the sea-waves must have wielded broken ice, that at the time the stones received their final polish the ice must have been free from coarse sand, and that the sand by which the stones became enveloped was tranquilly introduced. He opposed the idea that the sand was derived by fresh water from the boulder-clay on the platform above the cave.

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[*] Printed *in extenso* in the 'Geological Magazine,' new series, decade 2, vol. ii, no. 11, pp. 539–544.

Queries and Remarks relative to existing Ice-action in Greenland and the Alps, compared with former Ice-action in the N.W. of England and Wales. By D. MACKINTOSH, *F.G.S.*

The author begins by discussing the question whether the so-called continental ice of Greenland be a true ice-sheet formed independently of mountains, or merely an exaggeration of a confluent system of glaciers. [This and several other questions, furnished by the author, were incorporated with the Instructions for the Arctic Expedition.] He then goes on to consider the state of the surface of the Greenland ice-sheet, and believes that the amount of moraine matter is locally limited and of small extent. In query 3 he defends the idea of the internal purity of existing ice-sheets; and in query 4 he states reasons for doubting whether glaciers are capable of persistently pushing forward the large stones they may find in their beds, though he admits that the base of glaciers is charged with finer débris by means of which they grind and striate rock-surfaces. He mentions that in the Lake-district he had never seen a *sharply bordered* groove on a glaciated rock-surface which might not have been produced by a stone smaller than a walnut. He then quotes Forbes and Lyell to the effect that scarcely any of the stones found in the moraines of existing Alpine glaciers are polished or striated; and this leads him to ask, in query 6, whether the base of the Greenland ice-sheet be capable of holding stones firmly fixed in its grasp. He states reasons for doubting this; and after referring to the paucity of *uniformly striated* small stones among the mountains of the Lake-district and Wales, which once must have been covered with an ice-sheet or ice-sheets, compared with the abundance of regularly glaciated small stones in the boulder-clay of the neighbouring plains, he proceeds to consider the geological action of icebergs, and believes that they carry more rocky débris in their base than on their surface. In query 10 he considers whether grounding icebergs can give a rounded form to submarine rocks, or glaciate downhill; and states reasons for believing that they can do so to a certain extent, but that dome-shaped *roches moutonnées* have been principally formed by land-ice. He sees no reason for doubting that revolving icebergs are capable of scooping out hollows in the rocky bottom of the sea, and thinks that lake-basins on the rocky summits of hills, or on watersheds, may have been produced in this way. He then gives reasons for supposing that the drift-knolls called *eskers*, where their forms are very abrupt, may have been partly formed by eddying currents or waves generated or intensified by ice-movements, which sometimes will set the sea in motion as much as sixteen miles off.

The principal and most original part of the paper is on the subject of *coast-ice*. The author brings forward a mass of testimony, accompanied by considerations which tend to show that floating coast-ice is the principal transporter and glaciator of stones, and that the uniformly striated stones found in the boulder-clay of the plains were both glaciated and transported by coast-ice. He enters minutely into a consideration of how stones, previously more or less rounded, became flattened and uniformly grooved on one, two, or more sides, the grooves on each side varying in their directions. He believes that many of the stones found in the boulder-clay of Cheshire must have been frequently dropped and again picked up by coast-ice during the passage from their original positions.

On certain Isolated Areas of Mountain-Limestone at Luckington and Vobster. By J. MCMURTRIE, *F.G.S.*

In a few introductory remarks the writer described the general structure of the Carboniferous rocks of Somersetshire, together with their relation to the older rocks on which they rest, and the secondary formations by which they are overlaid. He then proceeded to point out three remarkable outliers of Mountain-limestone occurring at Luckington and Vobster immediately to the north of the Mendip Hills, which, owing to their abnormal position, had long been the subject of curious speculation, and concerning which different authors had arrived at very opposite conclusions. The dimensions and situation of these limestone masses were described in detail. The largest of the three occurred at Upper Vobster, and measured 1150 yards in length by 300 yards in breadth; another at Luckington was 450 yards in length by 120 yards in breadth; while a third, called the Tor Rock, was of smaller dimensions. They were completely surrounded by Coal-measures, and occurred at a distance of from 1300 to 1900 yards from the principal outcrop of limestone in the Mendip range.

The writer then proceeded to explain the views of other writers on the subject, which may be classed under three heads:—First, the original fault theory of Dr. Buckland and the Geological Survey; second, the combined fault and anticlinal theory of Mr. H. B. Woodward; and third, the overthrow theory of Messrs. Greenwell, Moore, and others. As to the first two theories, he said the workings of adjacent collieries had failed to show any proof of their existence. He then proceeded to prove that the limestones in question were superficial masses of no great thickness, and that they did not extend downwards to connect with the great underlying mass of Mountain-limestone, for the workings of several mines and one or two wells had proved the existence of Coal-measures beneath them at a comparatively shallow depth.

He expressed his belief in the theory that, during the upheaval of the Mendips and the inversion and crumpling-up of coal-strata which accompanied it, the limestone masses of Luckington and Vobster were in some way carried over from the Mendip range, and so rested upon the Coal-measures instead of lying far beneath them. The paper was explained by numerous diagrams and sections, the latter showing that the Mendips had originally attained a much higher elevation, and that the limestone strata removed by denudation were probably more nearly vertical than those which remain, if indeed the beds were not partially folded over in the same way as the Coal-measures.

On the Age of the Durdham Down Deposit, yielding Thecodontosaurus *&c.*
By Charles Moore, *F.G.S.*

About forty years ago some conglomerates were opened up apparently resting on the Carboniferous Limestone of Durdham Down, in which were found scattered reptilian remains, described by Messrs. Riley and Stutchbury under the names *Thecodontosaurus* and *Palæosaurus*. They were then supposed to be of Permian age, but are now referred to the Magnesian Limestone. The author believed them to be still more recent, and that they belonged to the Rhætic period.

In support of this conclusion he referred to a paper by himself published in the 'Geological Journal' for 1867 *, in which he showed that over a large area in the Mendip district the Carboniferous Limestones had formed the floor of the seas of more recent geological epochs, and, having become fissured, those fissures had been filled with the organic and other contents of more recent periods, these being shown to be as wide apart as from Rhætic to Liassic times. In veins of the former age he had found a fauna of great interest, including the reptilia *Thecodontosaurus* and *Palæosaurus*, found only before at Durdham Down, and amongst the fish-remains numerous examples of *Saurichthys apicalis* and *Acrodus minimus*.

The author then showed that precisely similar physical, mineralogical, and palæontological conditions were to be found on the tableland of Durdham Down, where numerous veins, one of them 18 feet in thickness, traversed the Carboniferous Limestone. One of these, near the Zoological Gardens, was proved to be of the age of the Lower Lias—Ammonites, *Echini*, Foraminifera, and other remains of that age being exhibited by the author taken from between the walls of the Carboniferous Limestone 30 feet from the surface. In another vein near the Suspension

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* "On Abnormal Conditions of Secondary Deposits &c. when connected with the Somersetshire and South Wales Coal-basin."

Bridge he had found numerous scattered fish-remains of Rhætic age, including *Saurichthys* and *Acrodus*, mentioned above, found also with the *Thecodontosaurus* and *Palæosaurus* on the Mendips; and he could therefore come to no other conclusion than that the deposits were equivalents in time, and that the Durdham Down reptilia must be referred to the Rhætic age rather than to the Magnesian Limestone.

On the Distribution of Flint in the Chalk of Yorkshire. By J. R. MORTIMER.

On Azygograptus, *a new Genus of Graptolites from the Skiddaw Slates. By* H. ALLEYNE NICHOLSON, *M.B., D.Sc., F.R.S.E., Professor of Natural History in the University of St. Andrews.*

In this communication the author recorded a new and remarkable genus of Graptolites from the Skiddaw Slates, founded upon specimens obtained by Mr. W. R. Dover. To this genus the name of *Azygograptus* was given; and in describing it the author associated Mr. Lapworth with himself, as he was greatly indebted to that gentleman for assistance in working out its true affinities.

The polypary in *Azygograptus* is simple and unilateral, consisting of a single monoprionidian stipe, which is developed from the central portion of the "sicula" on one side. The cellules are slightly overlapping.

This genus seems to be intermediate in its characters between the Nemagraptidæ and the true Monograptidæ, no member of the latter family having as yet been found in strata as old as the Skiddaw Slates. With the *Monograpti* the present genus agrees in the fact that the polypary consists of a single unicellular stipe; but it differs altogether from these in its mode of development, the celluliferous stipe springing directly from one side of the sicula about its centre. In this important character *Azygograptus* agrees with no other known Graptolites than *Nemagraptus*, Emmons, and *Cœnograptus*, Hall, both of these, however, including bilaterally developed forms. The cellules of *Azygograptus* are essentially of the type of *Monograptus Nilssoni*, Barr., and in this respect the genus is connected indifferently with either the Monograptidæ or the Nemagraptidæ.

The only known species of the genus was described under the name of *Azygograptus Lapworthi*. It is a slender form, about an inch in length as a rule, and hitherto obtained by Mr. Dover only in the Lower Skiddaw Slates of Hodgson-How Quarry, near Portinscale. It is very readily recognized, even in small fragments, by the unique appearance presented by the triangular sicula standing nearly at right angles to the slender celluliferous stipe. The fact also that the stipe originates from the centre of the sicula, below its broader end, gives it a most characteristic appearance, and prevents its being confounded with a broken *Didymograptus*.

On the Central Group of the Silurian Series of the North of England. By H. ALLEYNE NICHOLSON, *M.D., D.Sc., F.R.S.E., Professor of Natural History in the University of St. Andrews, and* CHARLES LAPWORTH, *F.G.S.*

In this communication the authors record the results of their investigation of the central series of Silurian deposits which intervene between the *Borrowdale series* of volcanic rocks ("Green Slates and Porphyries") on the one hand, and the *Coniston Flags* on the other. They conclude that the series in question may be naturally grouped as follows, in ascending order:—

A. The CONISTON LIMESTONE SERIES, composed of
  a. The *Dufton Shales*.
  b. The *Coniston Limestone*.
  c. The *Trinucleus Shales*.

B. The CONISTON MUDSTONE SERIES, composed of
  a. The *Skelgill Beds*.
  b. The *Knock Beds*.

The *Dufton Shales* are shown to constitute a mass of fossiliferous shales underlying the *Coniston Limestone*, without the intervention of any igneous rock of contemporaneous origin. They pass upwards into the limestone, and are about 300 feet thick under the Pennine chain, but thin out in proceeding westwards. The *Coniston Limestone* is the only constant member of its series, and the *Trinucleus Shales* form a local group developed above it in the Sedbergh district. The entire *Coniston Limestone series* is shown to be identical with the limestones of Kildare and Pomeroy in Ireland and Girvan in Scotland.

The *Coniston Mudstone series* is divided into two distinct groups, the *Skelgill Beds* and the *Knock Beds*. The name of *Skelgill Beds* is given by the authors to a group of black graptolitic mudstones and shales, which seem rarely or never to exceed 60 feet in thickness, and which are found almost everywhere above the *Coniston Limestone*. These beds are replete with Graptolites belonging to an exceedingly well-marked group of forms, which can be precisely paralleled with the species characteristic of the highest beds of the *Moffat series* of the south of Scotland (*Birkhill Beds*). Similar Graptolites occur in certain black beds which occupy a similar position on the shores of Belfast Lough and elsewhere in Ireland.

The *Knock Beds* form a small but exceedingly well-marked group of rocks, which are typically developed near the village of Knock in Westmoreland, but are found everywhere surmounting the Skelgill graptolitic beds. They consist mainly of green and purple shales and grits, and have yielded two species of Graptolites, viz. *Monograptus priodon* and *M. Broughtonensis*, n. sp. The authors consider the *Knock Beds* to be the diminutive representative of the *Gala* and *Hawick Beds* of the south of Scotland. They conclude, further, that the entire *Coniston Mudstone series* is to be regarded as belonging to the *Middle Silurian* period—that is, to the period in which the *Lower* and *Upper Llandovery* and the *Tarannon Shales* of "Siluria" were laid down.

Finally, the authors conclude that the true *Coniston Flags* are to be entirely separated from the *Coniston Mudstone series*. They parallel the *Coniston Flags* with the *Denbighshire Flags* of North Wales and the *Balmae* and *Riccarton Beds* of the south of Scotland, and they regard them as forming the true base of the *Upper Silurian series*.

The Cause of the Glacial Period, with reference to the British Isles[*].

By CHARLES RICKETTS, *M.D., F.G.S.*

Some who consider that the Glacial Period was dependent on extreme cold caused by the winters occurring when the earth was in aphelion, with a greatly increased eccentricity of its orbit, have deduced inferences which do not appear to accord with present physical conditions. With great glacier systems, such as existed in North America and in Europe, the air would have had almost the whole of its moisture condensed out of it by the cold long before it reached the Arctic circle; consequently glaciers could not have existed on the water-slope of the land surrounding the Arctic Ocean any more than they do now; and, so far from an "ice-cap" covering the Arctic regions, there would not have been sufficient moisture left to form in it ice-floes so great or extensive as at present.

The increased accumulation of snow now taking place in Greenland is accompanied by subsidence of the land, whilst elevation is at the same time rapidly occurring in Norway and Spitzbergen; it is therefore not requisite to attribute "the *invariable* occurrence of submergence along with glaciation to change in the centre of gravity of the earth." The cause of the present subsidence of Greenland, as well as that in Britain during the Glacial Period, was ascribed to the effect which an increased weight of snow would have in forcing downwards the crust of the earth into its fluid substratum (see Geol. Mag. vol. ix. p. 119).

Previous to the Glacial Period the Gulf of Mexico extended as far north as the junction of the Mississippi and the Ohio, Florida was submerged, and an extensive belt of land on the east coast of the United States was covered by a sea having a tropical temperature. Such alterations in the coast-lines must have induced a condition of climate nearly approaching, if not similar to, that which is indicated by the beds of plant-remains found in Greenland, Iceland, and Spitzbergen.

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[*] Printed *in extenso* in the 'Geological Magazine' for December 1875.

Dr. Carpenter has demonstrated that the north-polar "set" or current (commonly called the north-east branch of the Gulf-stream) is dependent on diminution of temperature in the Polar regions, causing displacement by sinking of the surface sea-water rendered denser by cooling, and the consequent influx of lighter, that is warmer, water to supply its place. Increased severity of the winter in the north would therefore augment the volume and velocity of this current, and, *cæteris paribus*, thus render milder that of Britain. This appears to be in accordance with the persistent increase of cold in Greenland and Iceland simultaneously with recession of the glaciers in Norway and the occurrence of milder winters in Britain, and also with changes which occasionally take place of a more temporary character, as the occurrence of winters in America of exceptional severity, whilst the same seasons were remarkable for their mildness on the eastern shores of the Atlantic, and *vice versâ*.

Not only has the Gulf of Mexico extended far up the valley of the Mississippi, but a former depression of the land has occurred in the West-Indian Islands, to 2000 feet and even to 5000 feet; raised sea-beaches occur on the west coast in California; and the Gulf of California is but an extension of the Colorado river, which has been submerged. Subsidence to so great an extent on each side would in all probability affect the isthmus in a similar manner. If such a depression took place in certain areas to the extent respectively of 134 and 300 feet only, it would enable the waters of the Atlantic to flow into the Pacific Ocean. The fauna have been considered to afford indications of a former intercommunication of the two oceans by the identity or similarity of many of the Mollusca (Mr. P. P. Carpenter, Brit. Assoc. Report, 1846) and also of the Echinodermata ('Depths of the Sea,' p. 14) on each side. It is thus more than probable that a passage for the equatorial current has been afforded at Panama and Nicaragua. If it occurred to a considerable extent, the north-polar current would have had no higher temperature than that which it could derive from the temperate zone. Such a removal of the Gulf-stream is by most, if not all, considered sufficient to reduce the temperature so as to cause the formation of glaciers in Britain; but though the intense cold would condense the atmospheric moisture so as to cause extensive ice-floes between Greenland and Norway, there would have been but little remaining to be precipitated in the Arctic Ocean.

It was contended that the succession of Glacial Periods, having intervening times characterized by a mild or even genial climate, as demonstrated by Mr. James Geikie, might have been caused by successive depressions and upheavals of the Isthmus of Central America. To obtain positive proof of this supposed change in the direction of the equatorial current, it is requisite that investigations with this object in view be made in Nicaragua and other parts of Central America.

On certain large Bones in Rhætic Beds at Aust Cliff, near Bristol.

By WILLIAM SANDERS, *F.R.S.*

In the year 1844 a large cylindrical bone was found on the shore at Aust by Mr. Edmund Higgins, from whom it was subsequently purchased for the Bristol Museum. It measures about 15 inches in length and about 17 inches in circumference. About four years later Mr. Alexander Thompson, residing near Aberdeen, found the largest of the bones, and generously presented it to the Museum. This is about 25 inches in length, and about equal to the other in circumference, that is, about 17 inches. A third bone, the smallest of the three, was found a few years ago, with a large vertebra, closely adjoining the thick "bone-bed;" it is 8 inches long, with a circumference of 15 inches.

Neither of these pieces had retained its terminations; they were therefore incomplete fragments. The two larger concurred in having a long furrow, apparently adapted to receive an artery or vein; and the late Mr. Samuel Stutchbury, who was then Curator of the Museum, observed that an analogous furrow passed along the femur of the frog, and suggested that these bones might have belonged to some huge Batrachian allied to the Labyrinthodon. A few years ago Professor Huxley saw the bones, and remarked that Mr. Stutchbury's determination could not possibly be correct.

Subsequently I took them to Oxford, so that they might be examined by my late estimable friend Professor Phillips. He immediately brought into comparison with the large bone the femur of a *Megalosaurus*. It was observed that the femur, as well as the bone in question, was covered with minute longitudinal indentations; also that these changed their course on approaching the process of the lesser trochanter. Now on the large bone there was a slight protuberance, and the longitudinal markings changed their direction on approaching it. If, then, this small protuberance were the remains of a larger one constituting a lesser trochanter, the resemblance between the bone in question and the femur of the *Megalosaurus* would become very insignificant. The great difference would consist in their relative dimensions, the circumference of the femur being about 13 inches, while that of the bone is about 17 inches.

Now it might be supposed that I should venture on the conjecture that we have before us the remains of a very large species of *Megalosaurus*; but I refrain from this because there is a striking difference in one respect between the two limbs that have been thus compared. Phillips says "the femur is, or appears to be, internally hollow." It will be seen that the Rhætic bones are, on the contrary, solid throughout.

I do not know of any other definite character requiring notice. My object is to draw attention to these remarkable remains, so that if any explorer of Rhætic strata should find in any other locality large bones of mysterious character, he may remember these, and bring his discovery into comparison with the bones of the Bristol Museum.

On Auriferous Limestone at Walton.

By W. W. Stoddart, *F.C.S.*, *F.G.S.*, *&c.*

Mr. Stoddart described the unusual occurrence of the presence of gold and silver which Mr. Pass and he had discovered in a sample of Carboniferous Limestone taken from a quarry in the neighbourhood of Clevedon. The limestone contains more than 94 per cent. of carbonate of lime, and is sufficiently pure to be used in the manufacture of glass, the principal impurity being oxide of iron. The author remarked the absence of sulphur and silica which so often accompany gold deposits, but which in the present case were absent. The analysis of the dried limestone gave the following:—

Aluminium	·8777
Ferric oxide	4·8000
Calcic carbonate	94·3000
Silica	·0200
Silver	·0023
Gold	a trace
	100·0000

In order to corroborate the results of the analyses which they had made, samples were sent to Mr. J. P. Merry, a well-known assayer at Swansea, who completely verified the fact of there being gold and silver present in the limestone. Although the quantity of these metals is exceedingly small, yet the fact of their occurrence in carboniferous limestone at all is exceedingly interesting and unusual. The amount of silver present in the limestone varies in different samples, one sample containing 94 grains per ton, while another contains nearly an ounce. The quantity of gold present varies from 3 to 5 grains per ton. The limestone is granular, and, when magnified, shows a great number of specks of oxide of iron; the presence of pyrites was carefully looked for, but none could be detected. It is very difficult to account for the origin of these metals; in the part of the quarry from which the samples were taken the limestone appeared much weathered, and darker in colour than the rest of the beds; yet no line of demarcation could be discovered which separated it from the other strata, as would have been the case had there been an intrusion of foreign matter; the other parts of the quarry appeared throughout tolerably uniform. The specimens of the metals and the limestone in different states were placed before the members of the Section.

On Changes of Climate during the Glacial Period.
By the Rev. W. S. SYMONDS, *F.G.S.*

On the Age of the Cannington-Park Limestone, and its Relation to Coal-measures South of the Mendips. *By* E. B. TAWNEY, *F.G.S.*

After noticing earlier opinions which gave a Devonian age to the limestone, the views of Mr. Baker were cited as the first expressed on the Carboniferous side. The latter origin was upheld by Mr. S. G. Perceval's determination of the corals in the Taunton Museum. The present author had found *Lithostrotion irregulare in situ,* which was held to be conclusive as to its Carboniferous age. The occurrence of Triassic veins intersecting the limestone was noticed. Theoretically the Carboniferous age makes more probable the existence of productive Coal-measures under the Somersetshire flats.

Discovery of a Submerged Forest in the Estuary of the Orwell.
By J. E. TAYLOR.

The author stated that his attention had been drawn to some peaty material which came from the bed of the river Orwell during the excavation of a new channel. Further investigation proved it to be 9 feet in thickness, full of recumbent trees, such as dwarf oak, pine, alder, &c., the lower part resting on a marl of freshwater shells &c., underneath which was the solid chalk. The peat-bed was buried beneath 6 or 8 feet of black river-mud. A series of thirteen excavations and dredgings conducted last November proved that the submerged forest extended for seven or eight miles. The peat-bed on an average was about 9 feet (in some places 14 feet) below low-water neap-tides. The tide rose 12 to 14 feet, and therefore, even if the old forest had grown at the sea-level, it must have stood about 30 feet higher than we now find. Mr. Taylor then referred to other post-glacial forest beds along the eastern coast, and expressed his belief that they represented the last stage of the continental condition of England before the depression took place which brought the North Sea over the low-lying plains, and so formed the present German Ocean. Some fine perfect teeth of the Mammoth (*Elephas primigenius*) were found in the Orwell forest-bed and exhibited.

Notes on the South-African Diamonds. *By* Professor J. TENNANT, *F.G.S.*

The first diamond was found in March 1867, and was pronounced by Dr. W. G. Atherstone to be genuine.

The number and quality of diamonds from the Cape are equal to those from the Brazils, which have chiefly supplied Europe during the last eighty years.

About 10 per cent. of the Cape diamonds may be taken as those of the first quality, 15 per cent. of the second, 20 per cent. of the third; the remainder, under the name of *bort,* are employed for cutting diamonds, and for the numerous applications to which this valuable substance is applied on the part of the glazier, the engineer for drilling rocks, the lapidary, and others. Many diamonds contain specks and cavities; these are placed in the hands of skilled workmen who are acquainted with the cleavage, and by careful manipulation they often get out portions of the first quality for making small "brilliants," "roses," and "tables."

It is estimated that the value of the diamonds found at the Cape, from March 1867 to the present time, exceeds twelve millions of pounds sterling.

On a new Genus of Rugous Corals from the Mountain-Limestone of Scotland. *By* JAMES THOMSON, *F.G.S.*

The author stated that this genus was closely allied to Dana's genus *Clissiophyllum*. It, however, differed from that genus, not only in its external aspect, but also very materially in the internal structure. He briefly described the characteristics by which the genus *Clissiophyllum* can be distinguished, viz. that there was always a conical boss in the centre of the calice, and that in the centre of the corallum there was always a columellarian line, which passed from the apex of the boss down the centre of the corallum, and terminated at the inferior extremity; and that there were lamellæ which passed from the inner margin of the primary septa into the columella in the centre of the calice, and that they were united by convex endothecal dissepiments, convexity upwards and outwards.

The genus he proposed to establish can readily be distinguished from *Clissiophyllum*, not only externally, but also from the internal structure. The boss in the centre of the calice never assumes a conical aspect, and is only slightly raised above the inner margin of the primary septa, and is divided in two by a strong middle ridge, from which the author derives the generic name. He is confident that the structure of the central portion of the corallum is more characteristic for generic distinction than any other part. We cannot, however, rely alone on that or any other part of the corallum for either generic or specific distinction. If it is taken, however, in conjunction with the other parts of the internal structure, it will enable us to readily decide as to what group the form ought to be classified with for diagnostic purposes.

DIBUNOPHYLLUM, gen. nov., Thomson.

Generic Characters. Corallum simple, cylindro-conical, tall in some forms, whilst in others it is short and more or less turbinate and marked with irregular accretion-ridges. Calice moderately deep, thin around the margin in some forms, whilst in others it is everted. Septa thin, with laminæ for fully half their length from the inner margin, wherein they become flexuous. Columellarian boss slightly raised above the inner margin of the primary septa, with a prominent middle ridge, which, in a transverse section, is seen to be formed of convex endothecal dissepiments, convexity outwards. The outer area is formed of lamellæ, which pass from the inner margin of the primary septa to the convex dissepiments of the median ridge.

A vertical section shows that the central area is dissimilar from the genus *Clissiophyllum.* Instead of a columellarian line in the centre of the corallum, as in the latter genus, there is a system of convex dissepiments, which converge to the centre, convexity outwards and upwards; whilst in other forms there are several vertical plates passing down the centre of the corallum, and each are united by concave endothecal dissepiments. Fossula with small septa in it.

This genus is established for the reception of a group of corals that the author discovered many years ago in Ponneil Water, five miles south of Lesmahagow, Lanarkshire. He has subsequently found them in several localities in the central valley of Scotland, details of which will be given hereafter, when the specific characteristics will be described in detail.

On the Occurrence of a Lower Boulder-clay or Till with Shells, in the Counties of Down and Mayo, Ireland. *By* WILLIAM A. TRAILL, *M.A.I.* (*Master in Engineering*), *F.R.G.S.I.*, *H.M. Geological Survey of Ireland.*

The author, in introducing his subject, briefly reviewed the divisions of the Drift series, especially so far as they related to the occurrence of shells in the lower boulder-clay, which he had met with in several localities in Ireland, and hoped that such places, and the mode of occurrence of such, would be carefully examined and noted, as only a few instances of these shelly drifts in Ireland had been recorded.

After long examination in the county Down, he was fortunate enough to find some shells in the undoubted lower boulder-clay in four localities adjacent to the

Kilkeel and Whitewater rivers. This district, lying to the S.E. of the Mourne Mountains, across which the ice-flow came from the N.N.W. and N.W., though obstructed and deflected, yet passing over elevations of at least 2000 feet, is covered by deep accumulations of drift, excellent sections of which are exposed in the river and sea-escarpments, some up to 120 feet in thickness. In these were seen the lower boulder-clay, or genuine till, resting on the denuded and often glaciated surfaces of the Silurian rocks, with subangular, rounded, and ice-scratched blocks firmly imbedded in a brownish clay, the lowest portion being chiefly a blue clay, and containing shells, mostly fragmental, those identified being *Turritella communis, Buccinum undatum, Leda rostrata.* Overlying this boulder-clay in the above cases, and as illustrated in diagrams, were the "interglacial sands and gravels," mostly horizontally bedded, and often forming extensive flat-land surfaces. Overlying these in places were accumulations of irregularly bedded gravels.

In the county Mayo, near Ballycastle, a section in the Glenulra river, 120 feet in depth, showed on top irregularly bedded coarse gravels for 25 feet, then evenly bedded fine gravels and sands for 30 feet, containing shell fragments, below which, though graduating from it, was some 50 feet of lower boulder-clay, the lowest part being a stiff plastic blue clay; in these, especially in the latter, the shell fragments were very abundant. In several localities adjacent, particularly in the stream Fiddawntawnanauneen, the specimens obtained were both numerous and very perfect; those identified were *Tellina proxima, Cyprina islandica,* and a *Balanus.* The author, without wishing to theorize on these deposits, wished only to add a few facts to the general store of knowledge regarding our drift deposits.

On a Mass of Travertine or Calcareous Tuff, called "The Glen Rock," near Ballycastle, County Mayo, Ireland. By WILLIAM A. TRAILL, *M.A.I. (Master in Engineering), F.R.G.S.I., H.M. Geological Survey of Ireland.*

The district in which this rock occurs is situated on the northern shore of the county Mayo, the rocks of the country consisting of Carboniferous sandstones and limestones, viz. white, brown, yellow, and red sandstones, with bands of shales, and pure and impure limestones, mostly inclined at low angles E.N.E. In that district several stalactite formations and deposits of carbonate of lime occur, the largest being "The Glen Rock," about two miles from Ballycastle, a mass of calcareous tuff and travertine resting on the eastern flanks of the valley along which the limestone beds crop out, approximately of the following dimensions:—length N. and S. 310 feet, E. and W. 285 feet, and in depth or thickness from 6 to 80 feet. The mass is irregular, and in cubic contents about 2,100,000 cubic feet. The tuff varies from a soft porous nature to a hard ringing travertine, and is composed chiefly of the casts or incrusted forms of diverse vegetations, of brambles, ferns, grasses, and ivy, &c., and containing the bones of birds and small animals, and shells of land-snails, &c. The origin of this large mass must be attributed to a large spring or "Holy Well," situated a little above on the slope of the hill. The water, by its passage through the limestone rock, becoming highly impregnated with lime, and by flowing over the vegetation on the slopes, has encased and cemented them together, and produced a much more vigorous growth, thus more rapidly building up this isolated mass of tuff, which stands out as a striking feature throughout the valley—the age of this mass being, of course, quite recent, after the present configuration of the country had been formed. There are evidences, however, that it has not increased in thickness for the last 300 years, as foundations of that age still exist on its highest summit; but now it seems to be rather breaking up under its own superimposed weight.

For upwards of twenty years a school was held in a natural cave in this rock, enlarged for the accommodation of sixty scholars, but which was closed in the year 1815. Since then the roof has subsided, filling it up for the most part. Various traditions connected with this rock were also noted, and specimens exhibited.

Note on the Reptilian Remains from the Dolomitic Conglomerate on Durdham Down. By Dr. THOMAS WRIGHT, *F.R.S.E.*

The author placed on the table the original specimens of *Thecodontosaurus* and *Palæosaurus* obtained from the dolomitic conglomerate of Durdham Down, and described by Dr. Riley and Mr. Stutchbury in the Geological Transactions, 1836. The author briefly described the principal characters of these remains, especially the jaw, teeth, vertebræ, and bones of the limbs, and which were all firmly imbedded in the conglomerate rock. He said the object he had in view in bringing this subject before the Section was to obtain an authoritative expression of opinion from the local geologists present as to the age of the conglomerate containing these Dinosaurian remains, as a doubt had been cast on the usually received opinion of the age of this formation in the late discussion which had taken place on the *Avicula contorta* or *Rhætic beds.* Mr. W. Sanders, whilst objecting to the term "dolomitic conglomerate," had nevertheless stated his conviction that the conglomerate formed part of the New Red Sandstone or Triassic series, and as such he had placed it in his geological map of the district. Mr. W. W. Stoddart, who admitted the conglomerate to be of Trias age, stated that he had analyzed the rock, and found it to be for the most part a double carbonate of magnesia and lime, and that it contained minerals found only in the Triassic rocks. Mr. Etheridge was also cited by the author as giving affirmative testimony to the same opinion; he therefore held that, with the evidence adduced, there could be no doubt that the dolomitic conglomerate was of Triassic age, and that the bones exhibited belonged to Dinosaurian reptiles of that period. This conglomerate rock was altogether different from the Liassic and other débris, rolled and rounded, that filled fissures in the Carboniferous limestone, of which they heard so much on a previous occasion. This conglomerate had been likened by one of the speakers in the *Avicula-contorta* debate to the matrix of these fissures; but the expression of opinion given to-day on this subject, he hoped, would remove the doubt that had been cast upon this point, and settle the question of the age of the dolomitic conglomerate, which was, he believed, a formation of the Triassic period.

BIOLOGY.

Address by P. L. SCLATER, *M.A., Ph.D., F.R.S., F.L.S., President of the Section.*

IN the office, which I have now held for more than sixteen years, of Secretary to the Zoological Society of London, I have been not unfrequently requested by our Members and Correspondents in various parts of the world to furnish them with information as to the best works to be consulted on the Zoology of the countries in which they are resident, or which they are about to visit. With the well-furnished Library of the Zoological Society at my command this is not usually a very difficult task, so far as publications are actually in existence to supply the desired information. I am also frequently asked to point out the principal deficiencies in our knowledge of the animals of particular countries. This is also a not very difficult request to comply with, although it is somewhat embarrassing on account of the very imperfect information which we still possess of geographical zoology generally, and the largeness of the claims I am therefore constrained to put forward for the attention of those who make such inquiries. Great, however, has been the progress made of late years towards a more complete knowledge of the faunas of the various parts of the earth's surface. Expeditions have been sent out into countries not previously explored; collections have been formed in districts hitherto little known; and many general works have been published combining the results of previous fragmentary knowledge on this class of subjects. Under these circumstances I have thought that such an account as I might be able to give of the general progress that has been recently made towards a better knowledge of the zoology of the various parts of the earth's surface, accompanied by a series of remarks upon the best available authorities to be consulted upon such subjects, might supply a want which, as above mentioned, I know, by personal experience, is often felt, and at the same time would form a not inappropriate address from the chair which I have now the honour to occupy.

I must premise, however, that my observations must be restricted mainly to the terrestrial members of the Subkingdom Vertebrata. To review the recent progress of our knowledge of the various sections of invertebrate animals in different countries would be beyond my powers, and would inordinately enlarge my subject. Besides, it is certain that the higher classes of animals have occupied the principal attention of recent writers on geographical zoology, and it is with the distribution of these classes that we are best acquainted.

Taking therefore in succession the seven great Regions into which the earth's surface may be most conveniently divided for zoological purposes, I will endeavour to point out our present leading authorities on the Mammals, Birds, Reptiles, Batrachians, and Fishes of each of them and their main constituent parts. At the same time I will endeavour to indicate the principal deficiencies in our knowledge of these subjects, and may perhaps be able to add a few suggestions as to how some of these deficiencies might be best overcome.

In these remarks I will take the divisions of the earth's surface in the same order as I have generally used in my lectures on zoological geography *, namely :—

I. Palæarctic Region	*Arctogæa.*
II. Ethiopian Region	
II*a*. Lemurian Subregion	
III. Indian Region	
IV. Nearctic Region	
V. Neotropical Region	*Dendrogæa.*
V*a*. Antillean Subregion	
VI. Australian Region	. . *Antarctogæa.*
VII. Pacific Region	. . . . . . *Ornithogæa.*

I. THE PALÆARCTIC REGION.

The Palæarctic Region I shall consider for convenience' sake in the following seven subregions :—

1. The *Cisatlantean Subregion*, embracing all that part of the Palæarctic Region lying south of the Mediterranean Sea.

1*a*. *The Atlantic Islands.*

2. The *European Subregion.*

3. The *Siberian Subregion*, embracing the whole of Northern Asia.

4. The *Mantchurian Subregion*, containing Northern China and the adjoining part of Mongolia.

5. The *Japanese Subregion*, embracing the Japanese Islands.

6. The *Tartarian Subregion*, containing the great desert-region of Central Asia.

7. The *Persian Subregion*, embracing Persia, Asia Minor, and Syria.

1. The Cisatlantean Subregion.

As regards the zoology of the main western portion of this district (Tunis and Algeria) our knowledge may now be said to be pretty far advanced. The standard work on the subject is the 'Exploration Scientifique de l'Algérie' (1), published by the French Government, in which are treatises on the Mammals and Birds of Algeria by Loche, and on the Reptiles and Fishes by Guichenot. This work was commenced in parts in 1840; and the portions relating to the Mammals and Birds were, I believe, intended to be written by M. Vaillant, the artist of the Commission; but only the plates were issued; and the text, by Captain Loche, was not completed until 1867. A smaller and more convenient work for travellers is the last-named author's catalogue of the Mammals and Birds of Algeria (2) published in 1858; whilst upon the Freshwater Fishes, Gervais's article in the 'Comptes Rendus' for 1866 (3), and the memoir of Messrs. Playfair and Letourneux in the 'Annals' for 1871 (4), may be profitably consulted.

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* See 'Science Lectures for the People,' Sixth Series, 1874, No. 5, "The Geographical Distribution of Mammals. By P. L. Sclater." Manchester: Heywood, 1874.

As regards the Herpetology of Algeria, an excellent memoir on this subject, by Dr. Alexander Strauch, will be found in the fourth volume of the new memoirs of the Academy of St. Petersburg (5). Those who penetrate beyond the Atlas will find many references to the vertebrated animals of that district appended to Canon Tristram's 'Great Sahara' (6). Many interesting details about the birds of Tunis and Algeria will likewise be found in the papers communicated to 'The Ibis,' by Messrs. Salvin (7), Tristram (8), and J. H. Gurney, jun. (9).

Of Morocco and the extreme western portion of the Atlas our knowledge is as yet by no means so perfect. As regards the Birds of Tangier and its vicinity we have Colonel Irby's lately published volume on the Ornithology of the Straits of Gibraltar (10), in which the "observations on the Moorish Birds are in a great measure culled from the MSS. of the late M. Favier—a collector long resident in Tangier." But in the south of Morocco, in the Western Atlas, and surrounding district there is certainly a considerable *terra incognita* within easy reach of England, which has hitherto been almost inaccessible to naturalists, though the short expedition of Dr. Hooker, Mr Maw, and Mr. Ball in 1871 (of which a notice only has been published (11); but a complete scientific account is, I believe, in preparation) shows that it *may* be penetrated if proper precautions are taken.

1 *a*. THE ATLANTIC ISLANDS.

The Atlantean Island-groups of the Canaries, Madeira, and the Azores may perhaps be most naturally appended to this division of the Palæarctic Region. Our knowledge of the fauna of each of these three groups is tolerable, although there is of course much to be done in working up details. As regards the Canaries, the standard work is Webb and Berthelot's 'Histoire Naturelle des Iles Canaries' (12), published at Paris under the auspices of the Minister of Public Instruction. Dr. Carl Bolle has visited the group more recently, and has written several excellent articles in Cabanis's Journal on its Ornithology (13).

Madeira has had the advantage of the residence of several first-class English naturalists; I need only mention the names of Lowe, Vernon-Wollaston, and Johnston to establish this point. More than twenty years ago Mr. E. V. Harcourt, in his Sketch of Madeira (14) and in contributions to the 'Proceedings of the Zoological Society' (15) and 'Annals of Natural History' (16), gave us a good account of the Ornithology of Madeira. Mr. F. Godman has recently published an excellent article on the Birds of Madeira and the Canaries, in 'The Ibis' for 1872 (17), in which a complete résumé is given of the whole of our previous knowledge of this subject, together with the information obtained by the author himself during his expedition to those islands in 1871.

As regards the Fishes of Madeira, they have formed a subject of study of several excellent Ichthyologists. The Rev. R. T. Lowe made numerous communications to the Zoological Society of London upon them in the early days of the Society, and published in their 'Transactions' in 1839 a Synopsis of Madeiran Fishes (18), to which several supplements were afterwards added. Subsequently Mr. J. Y. Johnson took up the subject and made numerous additions to Mr. Lowe's experiences, which were mostly published by the same Society (19). Dr. Günther has likewise contributed to our knowledge of Madeiran Fishes (20); so that on the whole there is, perhaps, hardly any locality out of Europe with the Ichthyology of which we have a better general acquaintance.

For our knowledge of the higher animals of the third of the Island-groups above spoken of, that of the Azores, we are mainly indebted to the energy of Mr. F. D. Godman, who made a special expedition to those islands in 1865, with the object of studying their fauna. The results are embodied in his volume on the Azores, published by Van Voorst in 1870 (21). Morelet's work (22), previously published, is mainly devoted to the Land-shells; Mr. Godman is almost our only authority upon the Mammals, Birds, and other Vertebrates.

2. THE EUROPEAN SUBREGION.

To discuss, or even to give the titles of all the works that have been published on the Vertebrates of Europe would extend this address to far beyond its proper limits. I must content myself with a few words on the principal works which have appeared of late years, first, upon the zoology of Europe generally, and, secondly, upon the faunas of its chief political divisions.

A. *Mammals of Europe.*

To begin with the Mammals, our standard authority upon the European members of this class is Blasius's 'Naturgeschichte der Saugethiere Deutschlands und der angrenzenden Länder' (23); and an excellent work it is. Unfortunately, however, it does not extend into Southern Europe, where alone many of the more interesting forms of European Mammal-life make their appearance. A work founded on Blasius's volume and embracing the additional species of Mammals to be met with in Spain, Italy, and Turkey is very desirable; and it is with great pleasure that I have been informed that an energetic Member of this Association has already set some such undertaking before him. The only work of reference of this extent that I am at present acquainted with is Lord Clermont's useful 'Guide to the Quadrupeds and Reptiles of Europe,' published in 1859 (24).

As regards the constituent countries of the European Subregion, there are but few recommendable works devoted to the illustration of their Mammal-faunas. In England we have Bell's 'British Quadrupeds,' belonging to Mr. Van Voorst's excellent series (25). This remained long out of print, until its recent reissue in 1874 by the author (26) with the assistance of Mr. R. F. Tomes and Mr. Alston. For France, M. Gervais's 'Zoologie et Paléontologie Française' (27), enumerates both recent and fossil Mammals, though most regard is paid to the extinct Fauna. As regards Spanish Mammals, almost the only authority I am acquainted with is Rosenhauer's 'Thiere Andalusiens' (28), which, however, is very defective, the author having devoted himself principally to the study of the Invertebrates. Capt. Cook (afterwards Widdrington) was the original discoverer of several of the rarer Mammals of Spain; but the account of them in his 'Sketches' (29) is very meagre. A bare list of the Mammals of Portugal is given by Prof. Barboza du Bocage in the 'Revue Zoologique' for 1863 (30). Passing over to Italy, Bonaparte's 'Fauna Italica' (31) and Costa's 'Fauna del Regno di Napoli' (32) must be mentioned, though both are somewhat out of date. But the former work is still the only authority on certain of the rarer Italian species and local forms. A recent summary of Italian Mammals has been given by Prof. Cornalia in 'Italia' (33); but on the whole it must be allowed that a good work upon the Mammals of the Italian peninsula is still a desideratum. Of the Mammals of Switzerland, on the other hand, we have an excellent recent work by Dr. Fatio, forming the first volume of his 'Faune des Vertébrés de la Suisse' (34), in which special attention is devoted to the difficult groups of Rodents and Insectivores. No student of the European Mammal-fauna should omit to consult Dr. Fatio's work.

Passing to Eastern Europe, we find our state of exact knowledge as to the Mammals very defective. As regards Greece, we may refer to the French 'Expédition Scientifique en Morée,' in which there is a memoir on the Mammals by Geoffroy St.-Hilaire (35), and Erhard's 'Fauna der Cykladen' (36) and Unger and Kotschy's volume on Cyprus (37), which give some details on the Mammals of the Greek archipelago. Of Turkey we find little or no information, and there is certainly still much to be done as regards the smaller Mammals of this part of Europe. In Southern Russia we have Ménétriés's Catalogue of the Animals of the Caucasus (38), and P. Démidoff's 'Voyage dans la Russie Méridionale (39), and perhaps other works in the language of the country, which I am not acquainted with. But there can be no doubt that it is in South-eastern Europe that our knowledge of the Mammal-fauna of this continent is very defective, and that most remains to be done in order to complete our acquaintance with this branch of European zoology.

In Northern Europe, which we now turn to, the case is quite different. The highly cultivated and laborious naturalists of Scandinavia have for many years paid great attention to this as to every other part of their fauna. The first volume of Nilsson's 'Scandinavian Fauna' (40), published at Lund in 1847, has long been a standard book of reference on this branch of zoology. Much, however, has been done since that period; and in Prof. Lilljeborg's lately issued work on the Mammals of Sweden and Norway (41), we have an exhaustive account of the present state of our knowledge of this subject.

As regards the few Mammals of Spitzbergen, reference should be made to the second volume of Heuglin's 'Reisen nach dem Nordpolarmeer' (42), where that energetic naturalist has put together an account of the nineteen species of Mammals that penetrate so far north.

B. *Birds of Europe.*

a. *Europe generally.*—There can be no question, I suppose, that the attractive class of Birds has received much more attention than its sister-classes of vertebrates in Europe, as generally elsewhere. Of late years especially a considerable number of naturalists in almost every part of this continent have bestowed their principal attention on Ornithology. Two journals are devoted solely to this science—in which the larger number of articles treat of the birds of some portion or other of Europe. The mass of literature on the subject is large; and I must therefore be rather concise in my notices of the principal modern authorities that should be referred to by an inquirer on European Ornithology.

First, as to the Avifauna of the whole continent, Temminck's 'Manuel' (43)—ong the acknowledged authority upon this subject—was superseded in 1849 by the issue of Degland's 'Ornithologie Européenne' (44). The new edition of this work, revised by Gerbe and issued in 1867 (45), is perhaps now the most complete book of its kind. But it has great faults and imperfections, particularly as regards its indications of the distribution of the species. This branch of the subject has never been properly worked out until the recent issue of Mr. Dresser's (formerly Sharpe and Dresser's) 'Birds of Europe' (46), which contains, so far as it has hitherto progressed, by far the most exhaustive account of the European Avifauna yet attempted. Its large size and numerous illustrations, however, render it rather cumbersome as a manual; but a handbook based on it when completed, and containing a judicious abridgement of its information, (which I hope Mr. Dresser will not fail to prepare,) would, I am sure, form a most valuable work.

Fritsch's 'Naturgeschichte der Vögel Europa's' (47), lately published at Prague, s a cheap and useful manual for those who understand German; while Gould's Birds of Europe' (48), though out of date, will be always referred to for its llustrations.

b. *Birds of Great Britain.*—For many years the standard book of reference on the Ornithology of these islands has been Yarrell's 'British Birds,' and its several Supplements (49). The new edition of this work, commenced in June 1871 by Prof. Newton (50), is familiar, no doubt, to most of the Members of Section D. As to its merits there can be no question; I think it is seldom indeed that a task s intrusted to one so thoroughly competent to perform it, or so careful in the execution of what he undertakes. But the slow progress of the work is appalling: after four years only one of the promised four volumes has been completed. As amongst the best of numerous local works on the Birds of this country recently ssued should also be mentioned Gray's 'Birds of the West of Scotland' (51), and Hancock's memoir on those of Northumberland and Durham (52). A very useful work of reference for Ornithologists is also Mr. Harting's 'Hand-book of British Birds' (53), in which the exact dates and places of occurrence of all the rarer visitants are recorded. Those who love life-sized illustrations, and have full purses, will not fail to acquire (provided a copy is left) Mr. Gould's splendid work on the Birds of Great Britain (54), now complete in five volumes. After this enumeration it will be almost needless to remark that Ornithology has no reason o complain of want of support in this country.

c. *Birds of France.*—In France less attention has been devoted to the native birds of late years; and besides the new edition of Degland's 'Ornithologie

Européenne' already spoken of, I have only to mention Bailly's 'Ornithologie de la Savoie' (55), and Jaubert and Barthélemy-Lapommeraye's 'Richesses Ornithologiques du Midi de la France' (56), in each of which will be found much information about the rarer birds of the districts respectively treated of.

d. *Birds of Spain and Portugal.*—Much attention has been paid to the Avifauna of Southern Spain of late years, but rather by visitors from the north than by native naturalists. Lord Lilford and Mr. Howard Saunders have both given us some excellent articles in 'The Ibis' on this subject (57, 58), and have made a variety of interesting discoveries, amongst which are actually several new species[*], or at all events well-marked local forms. Dr. R. Brehm, long resident at Madrid, has also devoted much attention to Spanish Ornithology, and written a complete list of Spanish Birds (59), which should be consulted. To Colonel Irby's work on the Straits of Gibraltar (10) I have already alluded; as regards the southern extremity of the peninsula he is our best and most recent authority. For information on the birds of Portugal we must again go to an English source, Mr. Alfred Charles Smith's Narrative of his Spring Tour (60) containing the best information which I am acquainted with on this subject.

e. *Birds of Italy.*—Savi's 'Ornitologia Toscana' (61), published as long ago as 1827, was for long almost our only authority on Italian Ornithology. Bonaparte's 'Iconografia,' already alluded to (31), gave some additional information as to rarer species. Salvadori's memoir on the Birds, forming the second volume of the recently published 'Fauna d'Italia' (62), is the best and most recent authority on this subject, and contains an excellent "Bibliografia Ornitologica Italiana." A large illustrated work on the birds of Lombardy has been recently published at Milan by Bettoni (63). I must also call attention to the persevering way in which Mr. C. A. Wright has worked up the Avifauna of Malta (64), and to Mr. A. B. Brooke's recently published notes on the Ornithology of Sardinia (65).

f. *Birds of Turkey and Greece.*—Dr. Kruper, a well-known German naturalist, has been long resident in various parts of the Levant, and has contributed numerous articles upon the birds met with to various periodicals. These have been recently put together and edited by Dr. Hartlaub, and published as a number of Mommsen's 'Griechische Jahreszeiten' (66), which thus contains a summary of all our principal information on the birds of Greece and its islands. Before that our best authority on Grecian birds was Lindermayer's 'Vögel Griechenlands' (67) As regards European Turkey, Messrs. Elwes and Buckley have lately published a good paper in 'The Ibis' on its birds (68); and MM. Alléon and Vian have written several articles in the 'Revue Zoologique' (69, 70) on the ornithology of the neighbourhood of Constantinople. But there is certainly still much to be done as regards birds in this part of the continent, as likewise amongst the islands of the Greek archipelago, many of which are almost unexplored by the naturalist.

g. *Birds of Southern Russia and the Caucasus.*—Though many notices of the birds of Southern Russia have appeared in the 'Bulletin' of the Society of Naturalists of Moscow, I am not aware of any complete account of them having been issued. Démidoff, in the third volume of his 'Voyage dans la Russie méridionale' (39), gives a list of the birds of what he calls the "Faune Pontique;" but his original observations are somewhat meagre. Eichwald's 'Fauna Caspio-Caucasica' (71) and Ménétriés's Catalogue of the Zoology of the Caucasus (38) should also be consulted, although both are rather out of date. An excellent zoologist, Hr. Gustav Radde, is now resident at Tiflis; but I do not think he has yet prepared any general account of the birds of the Caucasus, where there must be certainly much of interest, as is proved by the discovery of the remarkable Grouse, allied to our Black Grouse, which has just been described by M. Taczanowski[†].

h. *Birds of Germany and Central Europe.*—Local lists of the birds of the various states of Central Europe, and their principal divisions, are very numerous; and there are also many manuals and memoirs on the same subject. But J. A. Naumann's excellent 'Vögel Deutschlands' (73), commenced in 1822, with its supplements, is still, I believe, quite unsuperseded as a standard book of reference on

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[*] *Gecinus sharpii*, P. Z. S. 1872, p. 153, and *Calendrella bætica*, Dresser, 'Birds of Europe,' pt. 21.

[†] *Tetrao mlokosiewiczi*, Tacz., P. Z. S. 1875, p. 266 (72).

Central-European Ornithology. It was generally understood that Prof. Blasius, at the time of his lamented death, had a work on the birds of his native country in preparation; but unfortunately this was never finished; or it would have proved to be, no doubt, of first-rate excellence. In no other country, however, except our own, is Ornithology so much cultivated as in Germany. Two societies emulate each other in their pursuit of this science; and two special journals (74, 75) are devoted to its progress. There is no lack, therefore, of recent information upon the birds of every part of Germany, although this has to be fished out of journals and periodicals of different sorts, instead of being put together (as we should rather wish to see it) in some general work.

i. *Birds of Scandinavia and Northern Europe.*—In Scandinavia also there is no dearth of diligent observers of birds, as of every other class of animals. The Bird volume of Nilsson's Scandinavian Fauna (40) was published in 1858, and is still worthy of careful study. But the more recent works of Collett upon the Birds of Norway in German (76) and in English (77) should be consulted, as also Sundevall's 'Svenska Foglarna' (78), unfortunately not quite finished at the time of his decease, and von Wright and Palmén's 'Finlands Foglar' (79). Several memoirs have also recently appeared upon the birds of the extreme north, which have always attracted great interest among ornithologists. Amongst these, special attention may be called to:—v. Heuglin's account of the birds of Nova Zembla, first published in Cabanis's Journal for 1872 (80), and afterwards enlarged and revised in the second volume of his 'Reisen nach dem Nordpolarmeer;' to Prof. Newton's essay on the birds of Iceland, in Mr. Baring-Gould's 'Iceland, its Scenes and Sagas' (81); and, lastly, to Messrs. Alston and Brown's narrative of their adventures among the birds of Archangel (82)—a little-explored district, and one of much promise, to which one of these active explorers has returned this year.

C. *European Herpetology.*

In this field of research there is not so much of recent work to record as among the birds; but Dr. E. Schreiber's 'Herpetologia Europæa,' which has just appeared (83), marks an important epoch in this branch of science, since there was previously no good work of reference upon the Reptiles and Batrachians of Europe. Dr. Schreiber's work is drawn up upon the same plan as Blasius's well-known 'Säugethiere Europa's,' and forms a most convenient handbook. The list of published works and memoirs on the same subject prefaced to it renders it unnecessary for me to refer to the previous authorities on European Herpetology in detail. I observe, however, that Lord Clermont's very useful 'Guide to the Quadrupeds and Reptiles of Europe' (24) is not referred to in the list; and it would appear that Dr. Schreiber is not acquainted with it. I must also call special attention to Dr. Strauch's excellent memoir on the Serpents of the Russian Empire (84), recently published in the Memoirs of the Imperial Academy of St. Petersburg, which is as important for the European as for the Asiatic part of the Russian dominions. As regards our native Herpetological fauna also, I may point out that the last edition of Bell's 'British Reptiles' (85), published in 1839, requires considerable revision to bring it up to our present standard of knowledge, and that it is much to be desired that a new edition should be undertaken. Let me venture to suggest that Mr. Van Voorst should communicate with Dr. Günther upon this subject. In the meanwhile 'Our Reptiles,' by M. C. Cooke (86), may be used as a correct as well as popular guide to this branch of our fauna.

D. *European Ichthyology.*

I am not aware of the existence of any special work on European Ichthyology; but C. Th. v. Siebold published in 1863 a volume on the Freshwater Fishes of Central Europe (87), which forms a useful guide to the Piscifauna of the principal European river-basins. For the fishes of the Atlantic which visit the British coasts we have the third edition of Yarrell's 'British Fishes,' edited by the late Sir John Richardson (88), which was published in 1859. Now that Dr. Günther's great general work on Fishes has been completed, this portion of Mr. Van Voorst's excellent series would be also much benefited by revision and rearrangement according to Dr. Günther's modern system and nomenclature. As a cheaper and more popular work we may also refer to Couch's 'British Fishes,' in four volumes (89), of which the last was issued in 1865. In this book the figures are coloured.

Prof. Blanchard issued in 1866 a volume of the Freshwater-Fishes of France (90), which, however, does not bear so high a character as Siebold's work above referred to. For our knowledge of the fishes of Spain and Portugal we are chiefly indebted to Steindachner's memoirs in the Sitzungsberichte of the Vienna Academy (91), and to F. de Brito Capello's papers in the Journal of Sciences of Lisbon (92). Of those of Italy, Prof. Canestrini has lately published a revised list with short specific characters, as a section of the work called 'Italia' already referred to (93). Those interested in the fishes of the Black Sea and adjoining river-basins should consult the ichthyological portion of Démidoff's 'Voyage dans la Russie méridionale,' entitled "Pisces Faunæ Ponticæ." I am not acquainted with any other important recent memoirs on the Ichthyological faunas of the different European states which it is necessary to refer to until we come to Scandinavia, where Malmgren published in 1863 an excellent essay upon the Fishes of Finland, which was subsequently translated into German (94)*. As regards the Fishes of Spitzbergen and Nova Zembla, Heuglin's Synopsis of them in the second volume of his already quoted 'Reisen nach dem Nordpolarmeer' is the most recent authority, though it is principally founded upon the labours of Lovén and Thorell, and of the naturalists of the Swedish expeditions of 1861 and 1864.

3. The Siberian Subregion.

When I call to mind the numerous scientific expeditions sent by the Russians into different parts of their recent acquisitions in Northern Asia, and turn over the pages of the excellent and instructive works in which the results of these expeditions have been given to the world, I must own to a feeling of indignation at the manner in which such matters are usually dealt with by the Government of this country. In the first place, in order to get such an expedition sent out at all, great exertions and special influence are necessary. The Treasury must be memorialized, the Chancellor of the Exchequer besought, and the Admiralty petitioned, before any grant of money can be sanctioned for the purpose; and even then it is too often bestowed in a niggardly and grudging way. When the expedition returns, similar applications have to be made in order to get the results worked out and properly published; and these are in some cases altogether rejected, so that the money already spent upon collecting becomes virtually thrown away. In Russia, although the nation may be less awake to the claims of science than in this country, the Government is certainly more so; and it is to the scientific men attached to the Government expeditions that we are indebted for nearly all the knowledge we possess of the fauna of Northern Asia. Of the more important reports of the more recent of these expeditions I will say a few words.

Middendorff's 'Sibirische Reise' (95), published in 1847–67, gives an account of the fauna of the extreme north and east of Siberia. The second volume of the zoological section is entirely devoted to the Mammals, Birds, and Reptiles, and gives full details concerning the structure and habits of the species met with. Of Von Schrenck's 'Amur-Reisen' (96), a volume published in 1859 contains a complete memoir on the Mammals and Birds of the newly acquired district traversed by the Amoor, lying to the south of that investigated by Hr. v. Middendorff. Lastly, two volumes of Radde's 'Reisen in dem Süden v. Ost-Sibirien' (97), published in 1862 and 1863, render more perfect our knowledge of the Mammals and Birds of South-eastern Siberia. Hr. Radde's chief observations were made in Transbaikalia; but he incorporates the knowledge accumulated by his predecessors in the surrounding districts, and goes deeply into general results.

Dr. A. v. Middendorff's 'Isepipteseen Russlands' (98) should also be consulted by those who wish to understand the migration of birds in Siberia, or indeed throughout the Russian dominions.

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* See Zool. Rec. 1864, p. 136.

4. THE MANTCHURIAN SUBREGION.

Of this district, which embraces the country lying south of the Amoor and the greater part of Northern China, down perhaps to the great river Yang-tsze, we have, besides the Russian works lastly spoken of, two principal sources of information. The first of these consists in the researches of Mr. Robert Swinhoe, of H.M. Chinese Consular Service, one of the most industrious and successful exploring naturalists that have ever lived, who is well known to many of my brother Members here present. Mr. Swinhoe's memoirs and papers on Chinese zoology are very numerous; but his last revised list of the Birds of China (99) will be found in the Zoological Society's 'Proceedings' for 1871. Père Armand David, a worthy rival of our Consul, has likewise contributed in no small degree to our knowledge of the fauna of Northern China. His journals, containing numerous remarks full of interest, have lately been published in the 'Nouvelles Archives du Muséum d'Histoire Naturelle de Paris' (100); and M. Alphonse Milne-Edwards's recently completed 'Recherches sur les Mammifères' (101) contains a section specially devoted to the Mammals of Northern China, which is mainly based on Père David's researches. I shall, however, have again occasion to mention the discoveries of both Mr. Swinhoe and M. David in a subsequent portion of this address.

5. THE JAPANESE SUBREGION.

Temminck and Schlegel's 'Fauna Japonica' (102) has long been our standard authority upon the zoology of Japan; and not much has been done of late years to perfect it, except as regards the Birds. On this branch of our subject some very good articles have been published in 'The Ibis' by Capt. Blakiston (103, 104), based upon his researches in Hakodadi; by Mr. Whitely (105), who was for some time resident along with Capt. Blakiston at the same port; and by Mr. Swinhoe (106). Reference should also be made to the second volume of Commodore Perry's 'Narrative of the U.S. Expedition to Japan in 1852–54' (107), wherein will be found articles on the Birds collected, by Cassin, and on the Fishes, by Brevoort.

6. THE TARTARIAN SUBREGION.

Into the great desert-region of Central Asia, hitherto almost zoologically unknown, except from Eversmann's 'Reise nach Buchara' (108), which contains a short natural-history appendix, excursions have recently been made from two opposite quarters. The advancing tide of Russian conquest from the north, accompanied, as usual, by its scientific corps, has already made us well acquainted with the zoology of Turkestan. Mr. Severtzoff has unfortunately yielded to the unphilosophical spirit of nationality which has of late years attained such a monstrous development, and published his 'Turkestanskie Jevotnie,' or review of the distribution of animal life in Turkestan (109), in his native Russian. But a translation and reproduction of the portion relating to the Birds has already appeared in German (110); and an abstract of it in English is now being given to the world by Mr. Dresser in 'The Ibis' (111).

From the south the peaceful embassies of this country to Yarkand have led naturalists into the fringe of the same zoological district. Of the first of these expeditions we have an excellent account as regards the birds by Mr. A. O. Hume, forming the second part of Henderson's 'Lahore to Yarkand' (112). Sir D. Forsyth's second expedition to Yarkand and Kashgar was accompanied by Dr. Ferdinand Stoliczka, one of the most accomplished and energetic members of the staff of the Indian Geological Survey, whose life was miserably sacrificed to the hardships encountered on the return. Of this last expedition we have as yet only incomplete accounts *, but may, I trust, look forward to the publication of an equally interesting volume on the zoological results. The Ichthyological part of the collections has, I believe, been intrusted to Dr. F. Day to work out in this country.

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* See Hume, 'Stray Feathers,' ii. p. 513 (113), and iii. p. 215 (114).

7. THE PERSIAN SUBREGION.

Of the Persian or "Mediterraneo-Persic" Subregion, as Mr. Elwes prefers to call it*, which may be held to embrace European Turkey, Palestine, and Persia, our knowledge was until recently very limited, and even up to the present day remains very imperfect, considering the proximity of the district to Europe, and the many interesting features which it presents. As regards Palestine, Canon Tristram's energetic researches have done much to remove what has long been a scandal to biblical scholars as well as to naturalists. His long-promised 'Synopsis of the Flora and Fauna of Palestine,' however, is not yet issued by the Ray Society, and we must consequently be content with Mr. Tristram's papers on the Birds of the Holy Land in 'The Ibis' (115) and in the 'Proceedings' of the Zoological Society (116) and Dr. Günther's article upon the Reptiles and Fishes collected by Mr. Tristram (117), until the finished work appears. Of Asia Minor and Armenia it may be said that we are miserably ignorant, Tchihatcheff's desultory account of its Natural History in his 'Asie Mineure' (118) being almost the only authority we have to refer to. Thirty years ago the Zoological Society had two excellent correspondents at Erzeroom—Messrs. Dickson and Ross; and it is a great misfortune that no continuous account was ever prepared of the fine collections which they sent home†.

As regards Persia we may hope very shortly to be much more favourably situated. Mr. W. T. Blanford and Major St. John have recently made large zoological collections in various parts of that country, particularly of birds; and it is generally understood that the report of the Persian Boundary Expedition will contain a complete account of the zoology of Persia from Mr. Blanford's accomplished pen. Hitherto we have had to rely on De Filippi's 'Viaggio in Persia' (119) and other fragmentary sources of information.

II. THE ETHIOPIAN REGION.

This Region I shall speak of, for convenience' sake, under the following six subdivisions:—

1. *Western Africa*, from the Senegal to the Congo.
2. *South-western Africa*, or Angola and Benguela.
3. *South Africa*, *i. e.* the Cape colony and adjoining districts.
4. *South-eastern Africa*, from the Portuguese possessions up to the Somali coast.
5. *North-eastern Africa*, including Abyssinia, Nubia, and Egypt.
6. *Arabia.*

1. WESTERN AFRICA.

The Mammals of Western Africa are certainly not so well known as they should be; and there is no one work which gives an account of them, except Temminck's 'Esquisses Zoologiques sur la côte de Guinée' (1), which is devoted to the collections transmitted to Leyden by Pel, a most energetic and successful Dutch explorer. On the Mammals of Gaboon, Pucheran's article in the French 'Archives du Muséum' (2), and Du Chaillu's travels (3) and the literature connected therewith, should be consulted (4, 5, 6).

The Birds of Western Africa, on the contrary, have attracted much attention from European naturalists since the time when Swainson published his 'Birds of Western Africa' (7). This work, however, has been quite superseded by Hartlaub's classical 'System der Ornithologie Westafrica's' (8), published in 1857. Since that period many memoirs and papers have appeared on the birds of various parts of this district, principally by Cassin, of Philadelphia, Dr. Finsch, of Bremen, and Mr. R. B. Sharpe, of the British Museum, who has paid special attention to the African Ornis, and is understood to be preparing a general work on it.

For information on the Reptiles and Fishes of West Africa we must refer to Aug. Duméril's memoir (9) in the tenth volume of the 'Archives du Muséum d'Histoire Naturelle,' founded on the collections in the Paris Museum.

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* *Cf.* P. Z. S. 1873, p. 647.

† See notices of their collections in P. Z. S. 1839, 1842, and 1844.

2. South-western Africa.

The Portuguese colonies of Angola and Benguela, which seem to belong to a zoological subregion distinct from both that of West Africa and that of the Cape, were until recently almost unexplored. Within these last few years, however, Prof. Barboza du Bocage has acquired extensive series of specimens in nearly every department of natural history from these countries for the Lisbon Museum, and has published several important memoirs on the subject (10), which he will probably ultimately incorporate into a general work. Mr. J. J. Monteiro has also sent to this country collections of Mammals and Birds, which have formed the subject of several papers (11, 12).

3. Southern Africa.

Sir Andrew Smith's 'Illustrations of the Zoology of South Africa' (13) constitute four solid quarto volumes, devoted to the new and rare vertebrates met with during that energetic traveller's many explorations of the Cape colony and the adjoining districts, and supplementing Levaillant's celebrated 'Oiseaux d'Afrique' (14). But there is no perfect list of the Cape fauna given in Sir Andrew Smith's work; and therefore Mr. Layard's 'Birds of South Africa' (15), though not very completely elaborated, was a most acceptable and convenient work to the ornithologist. Still more agreeable will it be to witness the completion of the new and enlarged edition of Mr. Layard's little volume, which Mr. Sharpe has undertaken (16), and of which he has just issued the first part. Mr. Sharpe will, however, I trust, pardon me for remarking that he has cut the synonymy of the species rather short in his pages; it is hard to expect every South-African colonist to have at his side the British-Museum Catalogue of Birds, to which he always refers us. The omission of generic and family characters is also much to be regretted in a work of this kind. Another modern and much-to-be-recommended bird-book belonging to this subregion is Mr. J. H. Gurney's 'Birds of Damara-land' (17), founded on the extensive collections of the late C. J. Andersson. No less than 428 species of birds were obtained by that indefatigable collector; and the task of editing his field-notes has been well performed by Mr. Gurney.

4. South-eastern Africa.

Our knowledge of the fauna of Mozambique is chiefly due to the scientific visit made to that country by Dr. W. Peters, of Berlin, in 1842 and the following years. The volume of this distinguished naturalist's 'Naturwissenschaftliche Reise nach Mossambique' (18) on the Mammals was published in 1852, that on the Fishes in 1864. The delay in the issue of the portions relating to the Reptiles and Birds is much to be regretted, more especially when we consider the high standard of the work, although diagnoses of the new species discovered in these groups (19, 20) have been long since published; and I am sure I am expressing the sentiments of naturalists in general when I say that I hope to see the series shortly completed. Proceeding further north along the African coast, we come to Zanzibar, where an excellent ichthyologist, Consul Playfair, was lately resident. The 'Fishes of Zanzibar,' by Gunther and Playfair (21), founded on the extensive collections made by the latter, was published in 1866, and gives an account of above 500 species, and many excellent figures.

The Ornithology of the whole East-African coast, from Cape Gardafui to Mozambique, has been elaborately worked out by Drs. Finsch and Hartlaub. The results are contained in these authors' 'Vögel Ost-Afrika's' (22), forming the fourth volume of the unfortunate Baron Carl Claus von der Decken's 'Reisen in Ost-Afrika.' Full details as to previous authorities on the subject are given in this excellent work; so that it is not necessary to allude to them.

As regards the Mammals of this part of Africa, however, it is expedient to say a few words. Our knowledge of this class of animals is, as regards the coast opposite Zanzibar and the country surrounding the great lakes of the interior, mainly comprised in the fragmentary collections of Speke and Grant, of which an account has been published in the Zoological Society's 'Proceedings' (23), and in the few specimens transmitted by Dr. Kirk from Zanzibar*. There is no doubt, however, that much remains to be done here; and I believe there is at the present moment no finer field for zoological discovery available than this district, where we know that animal life in every variety is still abundant, and excellent sport can be obtained to add a zest to scientific investigation. The Fishes of the great lakes of Tanganyika and the Victoria and Albert Nyanza are likewise utterly unknown; and their investigation would be a subject of the greatest interest. Of those of the more southern Nyassa Lake, a few specimens were obtained by Dr. Kirk (24).

5. North-eastern Africa.

For many years Rüppell's 'Atlas' (25) and 'Neue Wirbelthiere' (26), and, as regards birds, his 'Systematische Uebersicht' (27), remained our standard works of reference upon the zoology of North-eastern Africa. The recent completion of Th. von Heuglin's 'Ornithologie Nordost-Afrika's' (28) has superseded Rüppell's volumes for general use; and no more valuable piece of work for ornithologists has been accomplished of late years than the reduction of the multitudinous observations and records of this well-known traveller and naturalist into a uniform series. Von Heuglin's work, however, concerns mainly Upper Nubia, Abyssinia, and the wide territory drained by the confluents of the Upper Nile. For Egypt and the Lower Nile a more handy volume is Capt. Shelley's 'Birds of Egypt' (29), published in 1872, which will be found specially acceptable to the tourist on the Nile. Nor must I forget to mention Mr. Blanford's interesting volume on the Geology and Zoology of Abyssinia (30), which contains an account of the specimens of vertebrates collected and observed during his companionship with the Abyssinian Expedition. Mr. Jesse's birds, collected on the same occasion, were examined by Dr. Finsch, and the result given to the world in a memoir published in the Zoological Society's 'Transactions' (31).

A good revision of the Mammal-fauna of North-east Africa is much to be desired. Meanwhile Fitzinger's list of v. Heuglin's collections (32), and the latter author's own account of them in his Travels on the White Nile (33), may be consulted.

The Appendix to Mr. Petherick's Travels in Central Africa contains a complete memoir on the Fishes of the Nile-basin, by Dr. Günther (34); while those of the Red Sea have lately formed the subject of study by Dr. Klunzinger, who has published an essay upon them at Vienna (35).

6. Arabia.

Of Arabia, as might have been expected, we know but little, zoologically or otherwise. But little, it may be said, can be expected to be found there, looking to the general aspect of the country. Still it would be of interest to know what that little is. At present the only district that has been visited by naturalists is the peninsula of Sinai; and of this our knowledge is by no means complete. Hemprich and Ehrenberg's unfinished 'Symbolæ Physicæ' (36) was for many years our sole authority. More recently Mr. Wyatt has published an article in 'The Ibis' upon the birds of the Sinaitic peninsula (37). Let me suggest to some of the officers who are stationed idle at Aden that an account of the animals to be met with in that part of Arabia would be of great value, and would give them much useful and interesting occupation. I have been more than once told that there is nothing whatever to be found there; but this I am slow to believe. Any one with a good pair of eyes and a taste for collecting might certainly do much good to science by passing a few months at Aden, and making excursions into that part of "Arabia Felix." In Herpetology, especially, new discoveries may be expected.

II *a*. THE LEMURIAN SUBREGION.

This aberrant portion of the Ethiopian Fauna I will speak of under two heads, namely:—

1. *Madagascar*. 2. *Mascarene Islands*.

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* E.g. *Colobus kirki*, Gray, P.Z.S. 1868, p. 180, pl. xv.

1. MADAGASCAR.

To our knowledge of the extraordinary fauna of "Lemuria," as I have elsewhere proposed to call Madagascar and its islands*, great additions have been recently made; but it is manifest that Madagascar is by no means yet worked out†. Dr. Hartlaub's 'Ornithologischer Beitrag zur Fauna Madagascar's' (38) was the first attempt at a *résumé* of the remarkable Avifauna of this part of the world. Since its issue two Dutch naturalists, Pollen and Van Dam, have visited Madagascar, and forwarded rich collections to the Leyden Museum. Of these the Mammals and Birds have been worked out by Professor Schlegel and Mr. Pollen, and the results published in a well-illustrated volume entitled 'Recherches sur la Faune de Madagascar.' This has been since followed by an accompanying account of the Fishes, and treatise on the Fisheries, by Messrs. Bleeker and Pollen (39). Following upon the footsteps of these naturalists, a French explorer, Alfred Grandidier, has since visited the interior of Madagascar, and in his turn has reaped a grand harvest, of which some of the results have already been given to the public (40). But we are promised to have these set before us in a much more extended and complete form, in a work now in progress, in which M. Grandidier has obtained the efficient assistance of M. Alphonse Milne-Edwards. There still remain to be spoken of the discoveries recently made by an English collector in Madagascar, Mr. A. Crossley. Mr. Crossley's birds have been worked out by Mr. Sharpe in several papers published from time to time by the Zoological Society (41); while Dr. Gunther has described several new and remarkable Mammals from the same source (42).

2. THE MASCARENE ISLANDS.

The Fauna of Bourbon, Mauritius, and Rodriguez forms an appendage to that of Madagascar, and merits careful study. Our knowledge of these islands, since the recent investigation of Rodriguez by the naturalists of the Transit-of-Venus Expedition, is tolerably complete, but requires to be put together, as it consists of fragments dispersed over various journals and periodicals. I trust that Mr. Edward Newton, who has had so many opportunities of acquiring information on this subject during his Colonial Secretaryship at Mauritius, and has so well used these opportunities, may shortly have leisure to devote to this task. His labours to recover the skeleton of *Pezophaps*, in which, I am pleased to think, he was aided by a grant from this Association, are well known, as is likewise the excellent memoir, by himself and Prof. Newton (43), in which the result of his labours was given to the world. Nor must I omit to mention Prof. Owen's dissertations on the fellow extinct bird of Mauritius, recently published by the Zoological Society (44, 45).

As regards the Recent Ornithology of these islands, we have nothing later to refer to than Hartlaub's little work on Madagascar, noticed above (38), which includes what was then known of the Avifauna of the Mascarenes.

The neighbouring group of the Seychelles was visited by Mr. Edward Newton in 1867, and several new and most interesting species of birds obtained there. A complete account of the ornithology of these islands was given by Mr. Newton in 'The Ibis' for 1867 (46). Since that period Dr. E. P. Wright, formerly an active member of this Association, has made a scientific excursion to the Seychelles, with the view, as was generally understood, of preparing a complete monograph of the fauna and flora of these interesting islands. It is much to be regretted that this very desirable purpose has not yet been accomplished.

III. THE INDIAN REGION.

Of the extensive and varied Indian Region I will now proceed to say something, under the subjoined heads:—

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* Quart. Journ. of Science, 1864, p. 213.

† Witness the Mammal-forms *Brachytarsomys* and *Mixocebus*, lately described by Dr. Günther and Dr. Peters, and the new genus of Birds, *Neodrepanis*, recently characterized by Mr. Sharpe.

1. *British India.*
2. *Central and Southern China.*
3. *Burmah, Siam, and Cochin.*
4. *Malay Peninsula.*
4a. *Andaman and Nicobar Islands.*
5. *East-Indian Islands.*
6. *Philippine Archipelago.*

1. BRITISH INDIA.

For British India Dr. Jerdon's well-known series of zoological handbooks was intended to supply a long-standing want; and it is a great misfortune that his untimely death has interfered with their completion. The three volumes on the Birds were finished in 1864 (1), and the one on the Mammals (2) in 1867. Of the volume on the Reptiles and Batrachians a portion, I believe, was actually in type at the time of his decease; but of the Fishes no part, so far as I know, was so much advanced. For the Reptiles, therefore, we must for the present refer to Dr. Gunther's 'Reptiles of British India' (3), published by the Ray Society in 1864; indeed, as regards India, any future account of these animals must, in any case, be founded upon the basis of that excellent and conscientious work. Mr. Theobald's Catalogue of the Reptiles in the Museum of the Asiatic Society of Bengal (4) should be also consulted. For the Indian Fishes generally there is at present no one authority, though Dr. Day, author of the 'Fishes of Malabar' (5) and of numerous other papers, is understood to have in preparation a general work on this subject, which his office of Inspector-General of Indian Fisheries has given him excellent opportunities of studying. Complete lists of both the freshwater and marine species of India are given in the appendices to Dr. Day's two 'Reports on the Fisheries of India and Burmah' (6 & 7), published in India in 1873.

But although our wants as regards the Indian Vertebrates will probably be supplied in this way, it would be much more satisfactory if the Indian Government would select a successor to Dr. Jerdon, and place under his control the necessary means for the preparation of a series of zoological handbooks for India. There is no reason why Botany should be more favoured than Zoology in this matter; and I believe it is only the greater energy of the botanists that in this, as in other cases, has given them the start. New editions of Dr. Jerdon's 'Mammals' and 'Birds' are both necessary to bring our knowledge up to date; and the original editions are long since out of print. There can be no question as to the great impetus to the study of Natural History in India that has already followed on the publication of these handbooks; and it will be a great misfortune to science if our Indian rulers fail to continue the good work. They have only to select a competent editor for the series, and to place the necessary funds temporarily at his disposal. The sale of the works will in the end more than recoup all the necessary expenses.

Amongst more recent contributions to our knowledge of Indian Ornithology, which, under the influence above referred to, have been especially numerous, I can now only stop to call attention to a few. Mr. Allan Hume, C.B., has been specially active, and has published numerous papers in his queerly-titled periodical 'Stray Feathers' (8), which is exclusively devoted to Indian Ornithology. Amongst them the articles on the birds of Scinde (9) and those of Upper Pegu (10) are of special interest. Mr. Holdsworth's most useful "Synopsis of the Birds of Ceylon," lately published in the 'Proceedings of the Zoological Society' (11), is also of great value, more especially as Ceylon was omitted from the scope of Dr. Jerdon's work. Nor must I omit to mention Major Godwin-Austen's series of papers (12) on the Ornithology of the newly-explored districts on the north-eastern frontier, which contain so much of novelty and instruction.

As regards the Testudinata of India, we may shortly expect a complete account of them from Dr. John Anderson, who has devoted much time and toil to their study. His magnificent series of drawings of these animals, from living specimens, I have had the pleasure of inspecting; and I trust sincerely that some means may be found of reproducing them for publication. Such a work would vastly increase our knowledge of this very difficult group of animals.

2. CENTRAL AND SOUTHERN CHINA.

In speaking of Northern China I have introduced the names of the two great modern zoological discoverers in China, Mr. Robert Swinhoe and M. le Père David. Mr. Swinhoe's article on the Mammals of China, recently published in the Zoological Society's Proceedings (13), gives a complete list of the species known to him to occur south of the Yangtsze. It includes those of the great island of Formosa, which is essentially part of China, although it possesses some endemic species, and which was a complete *terra incognita* to naturalists before Mr. Swinhoe's happy selection as the first British Vice-Consul in 1861. Mr. Swinhoe's last revised Catalogue of the Birds of China, published in 1871, has been already referred to. He is now at home, unfortunately in ill health, but is by no means idle on his bed of sickness, and has in contemplation, and, I may say, in actual preparation, a complete work on Chinese Ornithology, for which he has secured the cooperation of one of our most competent naturalists.

The still more remarkable discoveries of Père David have revealed to us the existence on the western outskirts of China, or rather on the border-lands between China and Tibet, of a fauna hitherto quite unknown to us, and apparently a *pendant* of the Himalayan hill-fauna first investigated by Hodgson. In his recently completed 'Recherches sur les Mammifères,' already referred to, M. Alphonse Milne-Edwards has given us a complete account of M. David's wonderful discoveries among the Mammals of this district. M. David's Birds were worked out by the late Jules Verreaux, and the novelties described in the 'Nouvelles Archives' (14); but no complete account of them has yet been issued. In Herpetology, I believe, M. David has also made some remarkable discoveries, amongst which, not the least, assuredly, is that of a second species of gigantic Salamander* in the mountain-streams of Moupin.

3. BURMAH, SIAM, AND COCHIN.

I speak of these ancient kingdoms, which occupy the main part of the great peninsula of South-eastern Asia, principally to express my surprise at how little we yet know of them. There are several good correspondents of the Jardin des Plantes in the French colony of Saigon, who have, I believe, transmitted a considerable number of specimens to the Muséum d'Histoire Naturelle; but beyond the descriptions of a certain number of novelties† we have as yet received no account of them. The two philosophic Kings of Siam appear not yet to have turned their attention to biological discovery, although there is certainly much to be done in the interior of that State, with which the late M. Mouhot, had his life been spared, would probably have made us better acquainted. As it happens we have only one published memoir (15) upon the results which this unfortunate naturalist achieved.

Lower Burmah now forms part of British India, and will be doubtless well explored. As regards Burmah proper and the Shan-states, our Indian legislators appointed a most efficient naturalist to accompany the Yunan Expedition of 1868 (16), but, when he returned, refused or neglected to provide him with the facilities to work out and publish his results. I rejoice, however, to learn that this error has been to a certain extent remedied, and that Dr. Anderson has now in preparation a connected account of his Yunan discoveries, which is to be issued by the Linnean Society in their 'Transactions.' A separate publication of these results, however, would not have involved much additional expense, and would have been more worthy of the Government which sent out the Expedition.

4. MALAY PENINSULA.

The Malay peninsula belongs unquestionably to the same Subfauna as Sumatra. Its zoology is tolerably well known to us from numerous collections that have reached this country, but a modern revision of all the classes of Vertebrates is much to be desired. About twenty years ago, Dr. Cantor, of the East-Indian Medical Service, published catalogues of the Mammals (17), Reptiles (18), and Fishes (19)

* *Sieboldia davidiana*, Blanchard.

† E. g. *Cercopithecus nigripes*, Milne-Edwards, and *Polyplectron germaini*, Elliot.

of Malacca in the Journal of the Asiatic Society of Bengal. To obtain a knowledge of its birds we must refer to the papers of Eyton (20), Wallace (21), and various other ornithological writers.

4 *a*. ANDAMAN AND NICOBAR ISLANDS.

The two groups of islands in the Bay of Bengal have of late years attracted considerable attention from naturalists. Port Blair, in the Andaman Islands, having become the seat of an Indian penal settlement, has received visits from several excellent Indian workers who have made extensive collections, especially in Ornithology. The most recent authorities upon the birds of the Andaman Islands are Lord Walden (22), who has worked out the series forwarded to him by Lieut. Wardlaw Ramsay, and Mr. Vincent Ball, who has published in 'Stray Feathers' a complete list of all the birds known to occur in the Andaman and Nicobar groups (23).

5. EAST-INDIAN ISLANDS.

Up to a recent period the standard authority on the fauna of the East-Indian Islands was the great Dutch work on the zoology of the foreign possessions of the Netherlands Government (24), based upon the vast collections formed by Macklot, Müller, and other naturalists, and transmitted to the Leyden Museum. This has been supplemented of late years by several works and memoirs of Dr. Schlegel, the eminent Director of that establishment and in particular by his 'Musée des Pays-Bas' (25), which contains an account of that magnificent collection drawn up in a series of monographic catalogues. Up to this time, however, Dr. Schlegel has only treated of the class of birds, though at the present moment, I believe, he is engaged on a revision of Quadrumana. To the class of Fishes, and especially to the Fishes of the Islands and Seas in the East Indies, another Dutch naturalist, Dr. P. P. Bleeker, has for many years devoted great attention. His memoirs and papers on the Ichthyology and Herpetology of the various islands and settlements are far too numerous to mention. But his 'Atlas Ichthyologique,' his principal work on the Fishes of the Indian Seas (26), is one of great importance, and claims a special notice as embracing the results of the life-work of one of the most energetic and laborious of living naturalists.

The travels of our countryman, Mr. Wallace, in the Malay Archipelago are well known to the general public from his instructive and entertaining narrative (27), and to zoologists from the large collections which he made in every branch of natural history. It is a misfortune that no general account of the latter has ever been prepared. But special articles on the birds of the Sula group to the east of Celebes (28), on those of Bouru (29), and on those of the islands of Timor, Flores, and Lombock (30), will be found in the Zoological Society's 'Proceedings,' besides other ornithological papers of Mr. Wallace referring more or less to this district.

Of the Island of Celebes we have acquired more intimate knowledge from the researches of Dr. A. B. Meyer, and from two excellent memoirs on its Ornithology, prepared by Lord Walden (31, 32). The adjacent territory of Borneo has likewise not escaped the attention of recent writers, an accomplished Italian author, Dr. Salvadori, having made it the subject of a special ornithological essay (33). For the animals of Java and Sumatra we have, unfortunately, no such recent authority, but must refer primarily in the one case to Horsfield's Zoological Researches (34), and in the other to Sir Stamford Raffles's Catalogue (35), supplementing in each case the deficiency by reference to various more recent books and memoirs. The fact is, that before we can attain precise notions as to the real zoological relations of these great islands, we require a much more complete research into their different faunas, and special monographic essays upon them. So there is certainly no lack of useful work remaining for the zoologist in this quarter.

6. PHILIPPINE ARCHIPELAGO.

In spite of the visits of Cuming, and more recently of Semper (36) and Jagor, there has been until very lately great want of a work for reference on the Vertebrates of the Philippine archipelago. This deficiency has been partly supplied by the excellent essay published by Lord Walden in the 'Transactions' of the Zoological Society, upon the Birds of the Philippines (37). Although based upon the collections of Dr. A. B. Meyer, this memoir contains a résumé of all that is yet known upon the subject. It likewise points out the deficiencies in our present information, which, I need hardly add, are many and numerous.

That our knowledge of the Mammal-fauna of the Philippines is also by no means perfect, will be sufficiently manifest when I recall to my hearers the fact that there is now breeding in the Zoological Society's Gardens a very distinct species of Deer *, quite unknown to all our Museums, which is undoubtedly endemic in one of the Philippine Islands. There is much want of more information on this subject, as also on the Reptiles and Fishes, although Dr. Peters has lately made us acquainted with many novelties from Jagor's researches in these branches (38–40).

IV. THE NEARCTIC REGION.

This part of my subject will be most conveniently treated of under two heads—

1. *North America down to Mexico,*
2. *Greenland,*—

leaving Mexico to be spoken of as a whole under the Neotropical Region, although part of it undoubtedly belongs to the Nearctic.

1. NORTH AMERICA.

a. *Mammals.*—The latest revision of the Mammals of North America is still that of Prof. Baird, contained in the Reports on the Zoology of the Pacific-Railway routes, published by the War Department of the U. S. in 1857 (1). I understand, however, that Dr. Elliott Coues is now engaged on a more perfect work, which will embrace the results of the large additions since made to our knowledge of this subject. The marine Mammals are not included in Prof. Baird's revision; and under this head I may notice two important works recently issued:—Dr. Allen's memoir on the Eared Seals (2), which specially treats of the North-Pacific species; and Capt. Scammon's volume on the marine Mammals of the North-western coasts of North America (3), which contains a mass of information relative to the little-known Cetaceans of the North Pacific. On the Bats of North America Dr. Allen has published a special essay in the 'Smithsonian Miscellaneous Collections' for 1864 (4).

Prior to the issue of these works Audubon and Bachman's 'Quadrupeds of North America' (5), published at New York in 1852, was the best book of reference.

b. *Birds of North America.*—The American Ornithologists have been specially active of late years. Up to about 20 years ago, the recognized authorities upon the Birds of the United States were Wilson (6), Audubon (7), Bonaparte (8), and Nuttall (9). In 1856 Cassin's 'Illustrations' (10), chiefly devoted to the species then recently discovered in Texas, California, and Oregon, appeared. In 1858 the joint work of Messrs. Baird, Cassin, and Lawrence, on the Birds of North America (11), forming part of the 'Pacific-Railway Routes,' was issued. This was republished with additions as a separate work in 1860 (12) in two volumes, and still forms an excellent book of reference on American Birds. The List of authorities given at the end of the letterpress will be found extremely useful for those who require a guide to the literature of American Ornithology. But even this bids fair to be superseded by the more recent publications of our energetic fellow naturalists. In the first place, three volumes of a 'History of North-American Birds,' illustrated by plates and numerous woodcuts, by Messrs. Baird, Brewer, and Ridgway (13), were issued last year; and two more volumes to complete the work will soon be ready. Then for those who require a handy book for reference nothing can be more convenient than Dr. Coues's 'Key' (14), in one volume, published in 1872. The same energetic naturalist has also lately issued a Handbook of the Ornithology of the North-west (15), containing an account of the birds met with in the region drained by the Missouri and its tributaries, amongst which he has had such long personal experience. Nor must I conclude the list without mentioning

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* *Cervus alfredi*, Sclater, P. Z. S. 1870, p. 381, pl. xxviii.

Mr. D. G. Elliot's 'Birds of North America' (16), which contains life-sized illustrations of many rare and previously unfigured species, and Cooper's 'Birds of California' (17), devoted to an account of the birds of the Pacific coast-region, which has been edited by Prof. Baird from the late Mr. Cooper's MSS. Of the last-named work, however, only the first volume is yet published. It will be thus seen that we have ample means of acquiring the most recent information on the birds of the Nearctic Region; and in fact in no part of the world, except Europe itself, is our knowledge of the endemic Avifauna so nearly approaching towards completion.

c. *Reptiles and Batrachians of North America.*—Holbrook's 'North American Reptiles,' in five quarto volumes, published at Philadelphia in 1842–4 (18), contains coloured figures of all the North-American Reptiles and Batrachians known to the author, and is a trustworthy work. A large amount of information has been acquired since that period, and published in the various "Railroad Reports" and periodicals by Hallowell, Baird, Cope, and others. In 1853 Messrs. Baird and Girard published a catalogue of North-American Serpents (19); and Prof. Agassiz devoted the first volume of his 'Contributions' (20) mainly to the Testudinata of North America. Prof. Baird tells me that Prof. Cope is now engaged in printing a new catalogue of the Reptiles and Batrachians of North America, which will contain an enumeration of all the species and an account of their geographical distribution.

d. *Fishes of North America.*—On the Fishes of North America there is up to the present time no one authority, and the inquirer must refer to the various works of Cope (21), Agassiz (22), and Girard (23) for information. This, aided by the copious references in Dr. Gunther's well-known Catalogue (24), he will have little difficulty in obtaining, so far as it is available. But the "History of American Fishes" is still to be written; and I have no doubt that our energetic brethren of the United States will before long bring it to pass.

2. GREENLAND.

Of Greenland, which is undoubtedly part of the Nearctic Region, I have made a separate section, in order to call special attention to the 'Manual' for the use of the Arctic Expedition of 1875, prepared under the direction of the Arctic Committee of the Royal Society (25). A résumé of all that is yet known of the biology of Greenland is included in this volume. I may call special attention to the article on the Birds by Prof. Newton, and on the Fishes by Dr. Lutken, both prepared specially for this work. I am sure you will all join with me in thanking the present Government for sending out this new Expedition so fully prepared in every way, and in hoping that large additions may be made to the store of information already accumulated in the 'Manual.'

V. THE NEOTROPICAL REGION.

The Neotropical Region is, I suppose, on the whole the richest in animal life of any of the principal divisions of the earth's surface*. Much work has been done in it as regards every branch of zoology of late years; and I must confine myself to noticing the most recent and most important of the contributions to this branch of knowledge.

I believe the following to be altogether the most natural subdivisions of this Region, which are nearly as they are set forth in Hr. v. Pelzeln's 'Ornithology of Brazil.'

1. *The Central-American Subregion,* from Southern Mexico to Panama.
2. *The Andean* or *Columbian Subregion,* from Trinidad and Venezuela, along the chain of the Andes, through Columbia, Ecuador, and Peru, down to Bolivia.
3. *The Amazonian Subregion,* embracing the whole watershed of the Orinoco and Amazons up to the hills, and including also the highlands of Guiana.

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* A general sketch of the Mammal-life of this Region is given in my article on the Mammals of South America, in the 'Quarterly Journal of Science' for 1865 (1). A systematic list of all the species of birds of the Neotropical Region is given in Sclater and Salvin's 'Nomenclator Avium Neotropicalium,' London, 1873 (2).

4. *The South-Brazilian Subregion*, containing the wood-region of S.E. Brazil and Paraguay and adjoining districts.
5. *The Patagonian Subregion*, containing Chili, La Plata, Patagonia, and the Falklands.

Besides these we have:—

6. *The Galapagos*, which, whether or not they can be assigned to any other Subregion, must be spoken of separately.

1. The Central American Subregion

was, up to twenty years ago, very little known, but has recently been explored in nearly every part, and is perhaps now more nearly worked out than any other of the above-mentioned Subregions. There is, however, as yet no complete work on the zoology of any portion of it; and the discoveries of Sallé, Boucard, de Saussure, and Sumichrast in Mexico, of Salvin in Guatemala, of v. Frantzius and Hoffman in Costa Rica, of Bridges and Arcé in Veragua, and of M'Leannan in Panama, together with those of numerous other collectors, are spread abroad among the scientific periodicals of Europe and America. Even of Mexican zoology, long as it has been more or less known, we have no general account. To mention all these memoirs in detail * would be impossible within the limits of this address; but I will say a few words about the more important of them that have lately appeared.

The French are now publishing a work on the results of their scientific expedition to Mexico during the short-lived Empire. Three parts on the Reptiles, by Duméril and Bocourt, were issued in 1870; and a part on the fishes, by Vaillant and Bocourt, has recently appeared (35).

A paper on the Mammals of Costa Rica has lately been published by v. Frantzius in Wiegmann's Archiv (36). Unfortunately, it seems to have been drawn up mainly from notes, without reference to the specimens in the Berlin Museum, but nevertheless contains much that is useful and of interest.

Dr. Gunther's admirable memoir of the Fishes of Central America, published in the Zoological Society's Transactions in 1869 (37), is based upon the collections made by Capt. Dow in various parts of the coast, and by Messrs. Salvin and Godman in the freshwater lakes of the highlands of Guatemala and in other localities. Its value in relation to our general knowledge of the fishes of this portion of America, heretofore so imperfectly known, can hardly be overestimated.

As regards the Birds of Central America, it is much to be regretted that we have at present no one authority to refer to. The collection of Messrs. Salvin and Godman embraces very large series from different parts of this region, and together with those of my collection, wherein are the types of the species described in my own papers, would afford abundant materials for such a task. Mr. Salvin and I have often formed plans on this subject; and I trust we may before long see the results of them. A similar memoir on the Mammals of Central America is likewise of pressing necessity for the better understanding of the Neotropical Mammal-fauna. There are considerable materials available for this purpose in the collections sent by Salvin and Arcé to the British Museum; and I hope that some naturalist may shortly be induced to undertake this task.

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* Some of the more important are M. de Saussure's papers on the Mammals of Mexico in the 'Revue Zoologique' for 1860 (3), sixteen papers by myself on the birds of Mexico, published in the Zoological Society's 'Proceedings' (4–19), two by myself and Mr. Salvin on the same subject (20, 21), Dr. O. Finsch's article on some birds from North-western Mexico, published at Bremen in 1871 (22), Prof. Sumichrast's notes on the birds of Vera Cruz, published at Boston in 1869 (23), and Mr. Lawrence's memoir on the birds of North-western Mexico in the second volume of the Boston Society's memoirs (24). As regards Guatemala, consult 'The Ibis' for 1859 and 1860, "Sclater and Salvin" (25, 26), and 1865 and 1866, "Salvin" (27, 28); for Honduras see G. C. Taylor in 'Ibis' 1860 (29); for Costa Rica consult Cabanis, Journ. f. Orn. 1860 (30), Mr. Lawrence's catalogue of Costa-Rican birds (31), and Mr. Salvin's remarks on it in 'Ibis,' 1869 (32). For Chiriqui refer to Mr. Salvin's memoirs (33) in P. Z. S. For Panama see Mr. Lawrence's Catalogue (Ann. L. N. York), and Messrs Sclater and Salvin's paper in P. Z. S. 1864 (34)

2. THE ANDEAN OR COLUMBIAN SUBREGION.

Of this extensive subregion, which traverses six or seven different States, there is likewise no one zoological account; but I may mention some of the principal works lately issued that bear upon the subject. Léotaud's 'Birds of Trinidad' (38) give us an account of the ornithology of that island, which forms a kind of appendage to this subregion; and Dr. Finsch has more recently published (39) a supplementary notice on the same subject. Of Venezuela, Columbia, and Ecuador there are only scattered memoirs in various periodicals on the numerous collections that have of late years been made in those countries to be referred to. Several excellent collectors are now, or lately have been, resident in these republics—Herr Göring and Mr. Spence in Venezuela*, Mr. Salmon in Antioquia, Professor Jameson and Mr. Fraser in Ecuador†—whose labours have vastly added to our knowledge of the zoology of these districts. When we come to Peru, we have Tschudi's 'Fauna Peruana' (55) to refer to, which, though unsatisfactory in execution, contains much of value‡. How far from being exhausted is the rich fauna of the Peruvian Andes, is sufficiently manifest from the wonderful discoveries lately made by Jelski in the district east of Lima, which was in fact that principally investigated by Tschudi. Of these, M. Taczanowski has lately given an account, as regards the birds, in the Zoological Society's 'Proceedings' (60); and Dr. Peters has published several notices of the more remarkable Mammals and Reptiles(61–62).

Further south, in Bolivia, our leading authority is still the zoological portion of D'Orbigny's 'Voyage dans l'Amérique Méridionale' (63). This rich and most interesting district has, it is true, been visited by several collectors since D'Orbigny's time; but the results of their journeys have never been published in a connected form, though many of their novelties have been described. Bolivia, I do not doubt, still contains many new and extraordinary creatures hid in the recesses of its mountain-valleys; and there is no part of South America which I should sooner suggest as a promising locality for the zoological collector.

3. THE AMAZONIAN SUBREGION.

On Guiana, where the Amazonian fauna seems to have had its origin, we have a standard work in Schomburgk's 'Reisen,' the third volume of which, containing the Fauna, was drawn up by the Naturalists of the Berlin Museum (64). For the valley of the Amazons itself, the volumes of Spix and Martius (65), though not very accurate, and rather out of date, must still be referred to—as likewise the Zoology of Castelnau's 'Expédition dans l'Amérique du Sud' (66), for the natural history of the Peruvian confluents. As regards the Birds, however, we have several more recent authorities. In 1873 Mr. Salvin and I published in the Zoological Society's 'Proceedings' a résumé of the papers treating of Mr. E. Bartlett's and Mr. John Hauxwell's rich ornithological collections on the Huallaga, Ucayali, and other localities in Eastern Peru (67–74). In 1867 we communicated to the same Society an account of Mr. Wallace's collection of birds made near Para (75), and took occasion to deduce therefrom some general ideas as to the relations of the Avifauna of the Lower Amazons.

As regards the valleys of the two great confluents of the Amazons, the Rio Madeira on the right bank, and the Rio Negro on the left bank of the mighty river, our knowledge of these Avifaunas is mainly due to the researches of Johann Natterer—one of the most successful and energetic zoological collectors that ever lived—of whose discoveries in ornithology a complete account has lately been published by Hr. A. v. Pelzeln, of Vienna (76). It is much to be wished that a similar résumé of Natterer's discoveries and collections of Mammals, in which Class his investigations were of hardly less importance, could be given to the world; and I trust Herr v. Pelzeln will forgive me if I press this subject on his attention.

The Fishes of the Amazons and its confluents are many and various, and fully deserve a special monograph. The late Professor Agassiz made his well-known expedition up the Amazons in 1865, with the particular object of studying its fishes, and amassed enormous collections of specimens for this purpose*. Whether (as other naturalists have hinted) Professor Agassiz's estimate of the number of new and undescribed species contained in his collections was exaggerated or not is at present uncertain, as the specimens unfortunately lie unstudied in the Museum of Comparative Zoology at Cambridge, Mass. It is a thousand pities this state of things should continue; and I venture to suggest to the great Professor's numerous friends and admirers in the United States that no more appropriate tribute to his memory could be raised than the publication of a Monograph of Amazonian Fishes based on these collections†.

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* See on these collections seven papers by Sclater and Salvin in P. Z. S. (40–46).

† See eight papers by Sclater in P. Z. S. 1858–60 (47–54).

‡ See also Sclater's papers on Prof. Nation's collections (56–59).

4. THE SOUTH-BRAZILIAN SUBREGION.

This subregion, which embraces the wood-region of S.E Brazil and adjoining districts, and contains in nearly every branch of zoology a set of species and genera allied to but separable from those of the Amazonian Subregion, has been much frequented by European naturalists. Its productions are consequently tolerably well known, though there is even here still very much to be done. Burmeister's 'Systematische Uebersicht' (77) and 'Erlauterungen' (78) may be referred to for information on its Mammals and Birds—likewise Prince Maximilian of Neu-Wied's 'Beiträge' (79), which, although of old standing in point of date, is still of great value. The late Dr. Otto Wucherer, a German physician resident at Bahia, paid much attention to the Reptiles of that district, and has written an account of its Ophidians, which will be found in the Zoological Society's 'Proceedings' (80). Hr. Hensel has also recently published in Wiegmann's 'Archiv' valuable memoirs on Mammals and other Vertebrates collected in South Brazil (81, 82), which should be referred to. Prof. Reinhardt has lately completed an excellent account of the Avifauna of the Campos of Brazil, based on his own collections and those of Dr. D. W. Lund (83); and Hr. v. Berlepsch has treated of the Birds of Santa Catharina (84). These are all most useful contributions to our knowledge of this Subregion. But it is melancholy to think that although a (*soi-disant*) highly civilized European race has occupied the Brazilian Empire so long, and has introduced railways, steamboats, and many other of the appliances of modern Europe, there has never, so far as I know, been produced amongst them any one single memoir worthy of mention on the teeming variety of animal life that everywhere surrounds their dwellings.

For information on the animals of Paraguay we must still refer to the writings of Don Felix de Azara (85), and to Dr. Hartlaub's reduction of his Spanish terms to scientific nomenclature (86). As regards the Mammals, there is also the more recent work of Rengger (87). But modern information about this part of the South-Brazilian Subregion would be very desirable.

5. THE PATAGONIAN SUBREGION.

For the zoology of the Argentine Republic, which forms the northern portion of this subregion, the best work of reference is the second volume of Dr. Burmeister's 'La Plata-Reise' (88), which contains a complete synopsis of the Vertebrates. Dr. Burmeister, who is now resident at Buenos Ayres as Director of the Public Museum of that city, has lately devoted himself to the study of the extinct Mammal-fauna, and specially to that of the Glyptodont Armadillos, of which he has lately completed a splendidly illustrated Monograph (89). He has likewise been the chief adviser of the Government in their plans for recognizing the University of Cordova, which will ultimately no doubt do much for the cause of Natural science in the Argentine Republic. Mr. W. H. Hudson, of Buenos Ayres, has long studied the birds and other animals of that country, and deserves honourable mention in a country where so few of the native-born citizens pursue science. His bird-collections have been worked out by Mr. Salvin and myself (90–92); and Mr. Hudson has likewise published a series of interesting notices on the habits of the species (93–100).

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* See 'Travels in Brazil,' by Prof. and Mrs. Louis Agassiz: Boston, 1868.

† Mr. Alexander Agassiz informs me that these collections are not so entirely unworked as I had supposed when this address was read. Dr. Steindachner has been through them; and Mr. Putnam has announced a "Catalogue of the Agassiz Collection of Fishes" as preparing for publication.

The 'Zoology of the Voyage of the Beagle' (101) contains much information concerning the animals of La Plata, Patagonia, and Chili. The "Mammals" by Waterhouse, the "Birds" by Gould and G. R. Gray, the "Fishes" by Jenyns, and the "Reptiles" by Bell, illustrated with notes and observations of Mr. Darwin, will ever remain among the leading authorities on the animals of this part of America. On the Rio Negro of Patagonia, where Mr. Darwin made considerable collections, we have a more recent authority in Mr. W. H. Hudson, whose series of birds from this district was examined by myself in 1872 (102).

Dr. R. O. Cunningham has recently followed on the footsteps of Mr. Darwin in Patagonia, and, besides his journal of travels, has published notes on the animals met with, in the Linnean Society's 'Transactions' (103). Mr. Salvin and I have given an account of his ornithological collections in several papers in 'The Ibis' (104).

As regards the Falkland Islands, two excellent collectors and observers—Capt. Packe and Capt. Abbott—have of late years been stationed there, and have provided the means of our becoming well acquainted with the native birds. Their collections have been examined by Mr. Gould and myself (105, 106); and Capt. Abbott has furnished many valuable notes on their contents (107).

Lastly, as regards Chili, we have Gay's somewhat pretentious 'Fauna Chilena,' forming the zoological portion of his 'Historia Fisica y Politica de Chile.' The volume on the Mammals and Birds was compiled at Paris by Desmurs, and that on the Reptiles and Fishes by Guichenot; but they are not very trustworthy. The German naturalists of the National Museum of Santiago, Philippi and Landbeck, have of late years published in Wiegmann's 'Archiv' many memoirs on the zoology of the Chilian Republic, of which I have given a list in a paper on the Birds of Chili in the Zoological Society's 'Proceedings' for 1867 (108). More recently Messrs. Philippi and Landbeck have published a catalogue of Chilian birds in the 'Anales de la Universidad de Chile' (109). But Mr. E. C. Reed, C.M.Z.S., who is likewise attached to the museum of Santiago, writes me word that he is now engaged in preparing for publication a complete revision of the Vertebrates of the Republic, which will no doubt give us still better information on this subject.

6. GALAPAGOS.

Until recently our knowledge of the very singular fauna of the Galapagos was mainly based upon Mr. Darwin's researches, as published in the 'Zoology of the Beagle,' above referred to. Recently, however, Mr. Salvin and I have described some new species of birds from these islands from Dr. Habel's collection (110); and Prof. Sundevall has published an account of the birds collected there during the voyage of the Swedish frigate 'Eugenie' in 1852 (111). Mr. Salvin has likewise prepared and read before the Zoological Society a complete Memoir on the Ornithology of the Galapagoan Archipelago, which will shortly be printed in the Society's 'Transactions.' Much interest has also been recently manifested concerning the gigantic Tortoises of the Galapagos, which Dr. Günther has reason to believe belong to several species, each restricted to a separate island*. Indeed I am much pleased to hear that the Lords of the Admiralty, incited by Dr. Günther's requests, have despatched H.M.S. 'Tenedos' of the Pacific squadron from Panama to the Galapagos, for the express purpose of capturing and bringing to England specimens of the Tortoises of each of the islands. We may therefore hope to be shortly more accurately informed upon this most interesting subject.

V*a*. THE ANTILLEAN SUBREGION.

The study of the fauna of the West-India Islands presents problems to us of the greatest interest:—first, on account of the relics of an ancient and primitive fauna which are found there, as indicated by the presence of such types as *Solenodon*, *Dulus*, and *Starnœnas*; and, secondly, from the many instances of representative species replacing each other in the different islands. Much, it is true, has been done towards the working-out of Antillean faunas of late years; but much more remains to be done; and indeed it is scandalous that there should be many islands under the British rule of the Zoology of which we are altogether unacquainted. The greater activity of our Botanical fellow-labourers has supplied us with a handy volume of the Botany of these islands*; and it is by no means creditable to the Zoologists to remain so far behind in this as in other cases already alluded to. Within the compass of the present address it would not be possible for me to enumerate all our authorities upon Antillean zoology; but I will mention some of the principal works of reference under the following heads:—

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* See 'Nature,' vol. xii. p. 238 (1875).

1. *The Bahamas.*
2. *Cuba.*
3. *Jamaica.*
4. *Haiti.*
5. *Porto Rico.*
6. *The Lesser Antilles.*

1. *The Bahamas.*

The late Dr. Bryant has published, in the 'Boston Journal of Natural History,' several articles upon the Birds of the Bahamas, where he passed more than one winter (112). These islands, however, merit much more minute investigation than has as yet been bestowed upon them.

2. *Cuba.*

Ramon de la Sagra's 'Historia Fisica y Politica de Cuba' (113), and Lembeye's 'Aves de la Isla de Cuba' (114), were up to a recent period our chief authorities upon Cuban zoology. But Cuba has long had the advantage of the residence within it of an excellent naturalist, Don Juan Gundlach, who has laboured hard towards the more complete investigation of its remarkable zoology. We are indebted to him for collecting the specimens upon which Dr. Cabanis based his revision of Cuban Ornithology, published in the 'Journal fur Ornithologie' (115), as also for a tabular list of Cuban Birds, published in the same journal for 1861 (116), and for several supplements thereto—for the more recent reviews of the Mammals and Birds of the island, published in the first volume of Poey's 'Repertorio'—and for many other contributions to the natural history of Cuba. This last-named work (117), as also the previous 'Memorias sobre la historia natural de la Isla de Cuba' of the same author (118), contain a number of valuable contributions to our knowledge of the rich fauna of this island, and should be carefully studied by those who are anxious to become acquainted with the peculiarities of the Cuban fauna.

3. *Jamaica.*

Mr. Gosse's meritorious work on the Birds of Jamaica (119), and his 'Naturalist's Sojourn' (120), are still the main source of our information on the fine island of Jamaica, and very little has been done since his time. A young English naturalist, Mr. W. Osburn, made some good collections in Jamaica in 1860, of which the Mammals were worked out by Mr. Tomes (121), and the Birds by myself (122). Mr. W. T. March has also more recently sent good series of the birds of the island to America; and Prof. Baird has edited his excellent notes on them (123). I must not lose the opportunity of calling special attention to the Seals of the Antilles (*Monachus tropicalis* and *Cystophora antillarum* of Gray), of which, so far as I know, the only specimens existing are the imperfect remains in the British Museum brought home by Mr. Gosse. More knowledge about these animals (if there be really more than one of them) would be very desirable.

4. *Haiti.*

Of this large island very little more is known as regards its zoology than was the case in the days of Buffon and Vieillot. Of its Birds alone we have a recent account in a paper which I prepared in 1857, upon M. Sallé's collection (124), and in a more recent memoir drawn up by the late Dr. Bryant, and published in the 'Proceedings' of the Boston Society of Natural History (125).

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* Griesbach's 'Flora of the West Indies.'

5. *Porto Rico.*

Nearly the same story holds good of this Spanish island, of which our only recent news relates to the Birds, and consists of two papers—one by Mr. E. C. Taylor in 'The Ibis,' for 1864 (126), and the other by the late Dr. Bryant, in the journal above mentioned (127).

6. *The Lesser Antilles.*

As I remarked above, every one of the numerous islands, from Porto Rico down to Trinidad, requires thorough examination. It is indeed strange that no one has yet been found to undertake this interesting task, which might easily be performed by excursions during the winter months of a few succeeding years.

As regards the Ornithology of these islands, the subjoined summary of what we really know and do not know is mainly taken from a paper on the Birds of Santa Lucia, which I read before the Zoological Society of London in 1871.

1. *The Virgin Islands.*—Of these islands we may, I think, assume that we have a fair acquaintance with the birds of St. Thomas, the most frequently visited of the group, and the halting-place of the West-Indian Mail-steamers. Mr. Riise, who was long resident here, collected and forwarded to Europe many specimens, some of which were described by myself*, and others are spoken of by Prof. Newton in a letter published in 'The Ibis' for 1860, p. 307. Mr. Riise's series of skins is now, I believe, at Copenhagen. Frequent allusions to the birds of St. Thomas are also made by Messrs. Newton in their memoir of the birds of St. Croix, mentioned below. In the 'Proceedings of the Academy of Natural Sciences of Philadelphia' for 1860 (128), Mr. Cassin has given an account of a collection of birds made in St. Thomas by Mr. Robert Swift, and presented to the Academy; twenty-seven species are enumerated.

Quite at the extreme east of the Virgin Islands, and lying between them and the St.-Bartholomew group, is the little islet of Sombrero, "a naked rock about seven eighths of a mile long, twenty to forty feet above the level of the sea, and from a few rods to about one third of a mile in width." Although "there is no vegetation whatever in the island over two feet high," and it would seem a most unlikely place for birds, Mr. A. A. Julien, a correspondent of Mr. Lawrence of New York, succeeded in collecting on it specimens of no less than thirty-five species, the names of which, together with Mr. Julien's notes thereupon, are recorded by Mr. Lawrence in the eighth volume of the 'Annals of the Lyceum of Natural History of New York' (129).

The remaining islands of the Virgin group are, I believe, most strictly entitled to their name so far as Ornithology is concerned; for no collector on record has ever polluted their virgin soil. Prof. Newton (Ibis, 1860, p. 307) just alludes to some birds from St. John in the possession of Mr. Riise.

2. *St. Croix.*—On the birds of this island we have an excellent article by Messrs. A. and E. Newton, published in the first volume of 'The Ibis'† (130). This memoir, being founded on the collections and personal observations of the distinguished authors themselves, and having been worked up after a careful examination of their specimens in England, and with minute attention to preceding authorities, forms by far the most complete account we possess of the ornithology of any one of the Lesser Antilles. It, however, of course requires to be supplemented by additional observations, many points having been necessarily left undetermined; and it is much to be regretted that no one seems to have since paid the slightest attention to the subject.

3. *Anguilla, St. Martin, and St. Bartholomew.*—Of this group of islands St. Bartholomew alone has, as far as I know, been explored ornithologically, and that within a very recent period. In the Royal Swedish Academy's 'Proceedings' for 1869 will be found an excellent article (131), by the veteran ornithologist Prof. Sundevall, on the birds of this island, founded on a collection made by Dr. A. von Göes. The species enumerated are forty-seven in number.

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* Ann. N. H. ser. 3, vol. iv. p. 225; and P. Z. S. 1860, p. 314.

† Ibis, 1859, pp. 59, 138, 252, and 365.

4. *Barbuda.*—Of this British island I believe I am correct in saying that nothing whatever is known of its ornithology, or of any other branch of its natural history.

5. *St. Christopher and Nevis*, to which may be added the adjacent smaller islands *St. Eustathius and Saba.*—Of these islands also our ornithological knowledge is of the most fragmentary description. Mr. T. J. Cottle was, I believe, formerly resident in Nevis, and sent a few birds thence to the British Museum in 1839. Amongst these were the specimens of the Humming-birds of that island, which are mentioned by Mr. Gould in his well-known work. Of the remainder of this group of islands we know absolutely nothing.

6. *Antigua.*—Of this fine British island, I regret to say, nothing whatever is known as regards its ornithology. Amongst the many thousands of American birds that have come under my notice during the past twenty years, I have never seen a single skin from Antigua.

7. *Montserrat.*—Exactly the same as the foregoing is the case with the British island of Montserrat.

8. *Guadeloupe, Deseadea, and Marie-galante.*—An excellent French naturalist, Dr. l'Herminier, was for many years resident as physician in the island of Guadeloupe. Unfortunately, Dr. l'Herminier never carried into execution the plan which I believe he contemplated, of publishing an account of the birds of that island. He sent, however, a certain number of specimens to Paris and to the late Baron de Lafresnaye, to whom we are indebted for the only article ever published on the birds of Guadeloupe (132), or of the adjacent islands.

9. *Dominica.*—Dominica is one of the few of the Caribbean islands that has had the advantage of a visit from an active English ornithologist. Although Mr. E. C. Taylor only passed a fortnight in this island in 1863, and had many other matters to attend to, he nevertheless contrived to preserve specimens of many birds of very great interest, of which he has given us an account in one of his articles on the birds of the West Indies, published in 'The Ibis' for 1864 (126). It cannot be supposed, however, that the birds of this wild and beautiful island can have been exhausted in so short a space of time, even by the energetic efforts of our well-known fellow-labourer.

10. *Martinique.*—This island is one of the few belonging to the Lesser Antilles in which birdskins are occasionally collected by the residents, and find their way into the hands of the Parisian dealers. There are also a certain number of specimens from Martinique in the Muséum d'Histoire Naturelle in the Jardin des Plantes, which I have had an opportunity of examining; but, beyond the vague notices given by Vieillot in his 'Oiseaux de l'Amérique Septentrionale,' I am not aware of any publication relating specially to the ornithology of this island. Mr. E. C. Taylor passed a fortnight in Martinique in 1863, and has recorded his notes upon the species of birds which he met with in the article which I have mentioned above; but these were only few in number. The International Exhibition in 1862 contained, in the department devoted to the products of the French colonies, a small series of the birds of Martinique, exhibited by M. Bélanger, Director of the Botanical Garden of St. Pierre in that island* (133). This is all the published information I have been able to find concerning the birds of Martinique†.

11. *St. Lucia.*—Of this island I gave an account of what is known of the birds in a paper published in the Zoological Society's 'Proceedings' for 1871, based upon a collection kindly forwarded to me by the Rev. J. E. Semper (134). Mr. Semper subsequently communicated some interesting notes on the habits of the species (135).

12. *St. Vincent.*—St. Vincent was formerly the residence of an energetic and most observant naturalist, the Rev. Lansdown Guilding, F.L.S., well-known to the first founders of the Zoological Society of London, who, however, unfortunately died at an early age in this island without having carried out his plans for a 'Fauna of the West Indies.' Mr. Guilding paid most attention to the invertebrate animals;

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* See article on Ornithology in the International Exhibition, 'Ibis,' 1862, p. 288.

† On animals formerly living in Martinique but now extinct, see Guyon, 'Compt. Rend.' lxiii. p. 589 (1866).

but his collections contained a certain number of birds, amongst which was a new Parrot, described after his decease by Mr. Vigors as *Psittacus guildingii*, which is a native of St. Vincent.

13. *Grenada and the Grenadines.*—Of the special ornithology of this group nothing is known.

14. *Barbadoes.*—The sole authority* upon the birds of Barbadoes is Sir R. Schomburgk's well-known work on that island (136). This contains (p. 681) a list of the birds met with, accompanied by some few remarks. It does not, however, appear that birds attracted much of the author's attention; and more copious notes would be highly desirable.

15. *Tobago*, I believe, belongs zoologically to Trinidad. Sir W. Jardine has given us an account of its ornithology from Mr. Kirk's collections (137).

VI. THE AUSTRALIAN REGION.

Of the Australian Region I will speak in the following Subdivisions:—

1. *Australia and Tasmania.*
2. *Papua and the Papuan Islands.*
3. *The Solomon Islands.*

1. AUSTRALIA AND TASMANIA.

That we know more of the fauna of Australia than of other English colonies in different parts of the world is certain; but no thanks are due from us for this knowledge either to the Imperial or to any of the Colonial Governments. The unassisted enterprise of a private individual has produced the two splendid works upon the Mammals and Birds of Australia which we all turn to with pleasure whenever reference is required to a member of these two classes of Australian animals. Mr. Gould's 'Mammals of Australia' was completed in 1863 (1). Since that period the little additional information received respecting the terrestrial Mammals of Australia has been chiefly furnished by Mr. Krefft of the Australian Museum, Sydney, in various papers and memoirs. Mr. Krefft has also written the letterpress to some large illustrations of the 'Mammals of Australia,' by Miss H. Scott and Mrs. H. Forde (2), in which a short account of all the described species is given. On the marine Mammals, which were scarcely touched upon by Mr. Gould, we have a treatise by Mr. A. W. Scott (3) published at Sydney in 1873, which contains a good deal of useful information concerning the Seals and Whales of the Southern Hemisphere†.

The magnificent series of seven volumes of Mr. Gould's 'Birds of Australia' (4) was finished in 1848. In 1869 a supplementary volume was issued, containing similar full-sized illustrations of about 80 species. In 1865 Mr. Gould reprinted in a quarto form, with additions and corrections, the letterpress of his great work, and published it under the title of a 'Handbook to the Birds of Australia' (5). This makes a convenient work for general reference. Of two Colonial attempts to rival Mr. Gould's series I cannot speak with much praise. Neither Mr. Diggles's 'Ornithology of Australia' (6) nor Mr. Halley's proposed 'Monograph of the Australian Parrots' (7) are far advanced towards conclusion; indeed of the last-mentioned work I have seen but one number.

Several large collections of birds have been made in the peninsula of Cape York and adjoining districts of Northern Queensland of late years; and it is a misfortune for science that we have had no complete account of them. One of the largest of these, however, made by Mr. J. T. Cockerell, has luckily fallen into the hands of Messrs. Salvin and Godman, and will, I trust, be turned to better uses than the filling of glass cases and the ornamentation of ladies' hats.

It seems to me that there is still much to be done even in Birds in Northern Australia; and I cannot help thinking that Port Darwin, the northern extremity of the trans-continental Telegraph, would be an excellent station for a collecting naturalist, and one where many novelties, both zoological and botanical, would certainly be met with.

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* A short note on a small collection of birds from Barbadoes was also published by me in the P. Z. S. 1874, p. 174 (138).

† A general view of the Mammal-fauna of Australia is given in an article which I published in the 'Quarterly Journal of Science' for 1865, p. 213.

On the Snakes of Australia we have an excellent work, published in 1869, by Mr. Gerard Krefft (8), one of the few really working Australian naturalists, who, however, it appears, is not appreciated by the Trustees of the Sydney Museum as he deserves to be. Mr. Krefft during his long residence in Sydney, has become well acquainted with the Ophidians of the Colony and has devoted special attention to them, so that he has the advantage of practical as well as scientific acquaintance with his subject. The late Dr. Gray has written many papers on the Tortoises and Lizards of Australia. Of the latter, we have to thank Dr. Gunther for a complete monographic list just published in one of the newly issued numbers of the 'Voyage of the Erebus and Terror' (9). Most of the plates of this work were also issued in 1867 by Dr. Gray in his Fasciculus of the Lizards of Australia and New Zealand (10).

For information on the Fishes of Australia reference must be made to the Ichthyological portion of the 'Zoology of the Erebus and Terror,' by Sir John Richardson (9), and to the same author's numerous papers on Australian Fishes in the 'Annals of Natural History' and 'Transactions' and 'Proceedings' of the Zoological Society of London (11-15). The Count F. de Castelnau, who seems to be almost the only working Ichthyologist in Australia, has recently published in the 'Proceedings of the Zoological and Acclimatization Society of Victoria' several papers on the Fishes of the Melbourne Fish-market and of other parts of Australia, which include a complete synopsis of the known Australian species (16-24).

2. Papua and its Islands.

I believe that my paper upon the Mammals and Birds of New Guinea, published by the Linnean Society in 1858 (25), was the first attempt to put together the scattered fragments of our knowledge of this subject. In 1859 a British-Museum Catalogue by Dr. J. E. and Mr. G. R. Gray (26), gave a résumé of the then known members of the same two classes belonging to New Guinea and the Aru Islands, and included notices of all Mr. Wallace's discoveries. In 1862 Mr. Wallace gave descriptions of the new species discovered subsequently to his return by his assistant, Mr. Allen (27). In 1865 Dr. Finsch published at Bremen an excellent little essay called 'Neu-Guinea und seine Bewohner' (28), in which is given a complete account of our then state of knowledge of the subject. But within these last ten years still more serious efforts have been made by naturalists of several nations to penetrate this *terra incognita*. Two emissaries of the Leyden Museum (Bernstein and v. Rosenberg) have sent home full series of zoological spoils to that establishment, and have discovered a host of novelties. Of these the Birds have been described by Prof. Schlegel in his 'Observations Zoologiques' (29). An intrepid Italian traveller, Signor L. M. d'Albertis, made a still further advance, when in September 1872 he accomplished the first ascent of the Arfak mountains *, and discovered the splendid Bird of Paradise and other new species which I described in 1873 (30). Quickly following on his footsteps Dr. A. B. Meyer penetrated still further into the unknown interior, and reaped the abundant harvest of which he has given us an account in six papers lately published at Vienna (31-36). Dr. Meyer has now become Director of the Museum of Dresden, and is no doubt occupied in the further elaboration of his rich materials. In the meanwhile some accomplished Italian naturalists are engaged on the collections of D'Albertis and his quondam companion Beccari. Count Salvadori, who is at work on the birds, will take the opportunity of preparing a complete account of the Ornithology of Papua and its islands, similar to that of Borneo, of which I have already spoken. The Marquis Giacomo Doria has already published one excellent paper on the Reptiles of Amboina and the Ké Islands collected by his compatriot Beccari (37), and is preparing other memoirs on the Mammals and Reptiles of New Guinea and the Aroo Islands obtained by D'Albertis.

Dr. Meyer has lately given an account of his Herpetological discoveries in New

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* See 'Nature,' vol. viii. p. 501.

Guinea, which comprehend several new and most interesting forms, in a memoir read before the Academy of Berlin (38); and Dr. Bleeker some years ago gave a list of the Reptiles obtained by v. Rosenberg in that island, and enumerated the Papuan Reptiles then known to him (39).

All these expeditions, however, have been directed towards the western peninsula of New Guinea, which alone is yet in any way explored by naturalists. Of the greater south-eastern portion of the island we have as yet very little information. A Cassowary * and a Kangaroo †, brought away by the 'Basilisk' from the southern coast, both proved to be new to science, as did likewise a Paradise-bird obtained in the same district by M. d'Albertis ‡. This is sufficient to give us an idea of what we may expect to find when the interior of this part of New Guinea is explored. And I may take this opportunity of mentioning that a most active and energetic traveller is perhaps at this very moment at work there. M. L. M. d'Albertis, of whose previous labours I have just spoken, returned to the East last autumn. Letters received from him by his Italian friends in June last state that he had at the time of writing already succeeded in reaching Yule Island near Mously Bay on the S.E. coast of New Guinea, and proposed to establish his head-quarters there for expeditions into the interior.

3. New Ireland, New Britain, and the Solomon Islands.

I devote a few words specially to these islands because they are easy of access from Sydney, and because their productions are of particular interest, belonging, as they do, to the Papuan and not to the Polynesian fauna. I have put together what is known of the birds of the Solomon's group in a paper read before the Zoological Society in 1869 (40). Seeing the interesting results obtained from the examination of one small jar of birds collected here by an unscientific person, there can be little doubt of the value of what would be discovered on the more complete investigation of the group. As regards New Ireland and New Britain, we have but scattered notices to refer to. The last-named island is, we know, the home of a peculiar Cassowary (*Casuarius bennetti*).

A list of the fishes of the Solomon Islands is given by Dr. Günther in Mr. Brenchley's 'Cruise of the Curaçoa' (41), which I shall allude to again presently.

VII. THE PACIFIC REGION.

Of this Region, where Mammals (except a few Bats) are altogether absent, and Birds are the predominant form of Vertebrate life, I will say a few final words under three heads:—

1. *New Zealand.* | 2. *Polynesia.* | 3. *The Sandwich Islands.*

1. New Zealand.

In New Zealand, of all our Colonies, most attention has lately been devoted to natural history, and several excellent naturalists are labouring hard and well; I need only mention the names of Dr. Hector, Dr. Haast, Capt. F. W. Hutton, and Mr. Buller. The commendable plan of affiliating the various local Societies to one Central Institute has resulted in the production of an excellent scientific Journal, already in its sixth volume, which contains a mass of most interesting papers on the fauna and flora of the Colony (1). To refer to these memoirs in detail is quite unnecessary; but it is obvious, on turning over the pages of the volumes of the 'Transactions of the New-Zealand Institute,' how great are the exertions now being made to perfect our knowledge of the natural products, both recent and extinct, of our antipodean Colony.

Mr. W. L. Buller's beautiful volume on the Ornithology of New Zealand, finished in 1873 (2), is likewise a most creditable production both to the author and to those who have supported and promoted his undertaking. Few, indeed, are the Colonies that can boast of a similar piece of work!

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* *Casuarius picticollis*, Scl., P. Z. S. 1875, p. 85.

† *Dorcopsis luctuosa* (D'Albertis), *v.* Garrod, P. Z. S. 1875, p. 48.

‡ *Paradisea raggiana*, Sclater, P. Z. S. 1873, p. 559.

In 1842 the late Sir John Richardson presented to this Association a special report on the Ichthyology of New Zealand (3); but much advance has, of course, been made since that period.

The Lizards of New Zealand have been recently enumerated along with those of Australia in Dr. Günther's memoir above referred to.

2. Polynesia.

Great additions have recently been made to our knowledge of the natural productions of the Polynesian Islands by the travellers and naturalists employed by the brothers Godeffroy of Hamburg. These gentlemen not only have extensive collections *made*, but also trouble themselves to get them properly *worked out*. The excellent volume on the Ornithology of the Fiji, Samoa, and Tonga Islands published in 1867 by Drs. Finch and Hartlaub (4), is based entirely upon materials thus obtained, as are likewise the many capital memoirs which fill the parts of the Illustrated quarto 'Journal des Museum Godeffroy' (5)—a journal replete with information upon the geography, ethnography and natural history of Polynesia. Amongst these memoirs I must call special attention to Dr. Günther's 'Fische der Südsee' (6), founded upon Mr. Andrew Garrett's splendid collection of fishes and of drawings of them coloured after life, of which three parts are already issued. We have now for the first time almost, in this country, the opportunity of becoming acquainted with the exceeding beauty of the tropical fishes in life!

The late Mr. Julius Brenchley's account of his cruise in H.M.S. 'Curaçoa' among the South-sea Islands (7), published in 1873, contains an appendix of "Natural-History Notices," illustrated by figures of remarkable specimens obtained on the occasion. Of these the part relating to the Birds is by the late Mr. G. R. Gray, and those concerning the Reptiles and Fishes by Dr. Günther.

3. The Sandwich Islands.

The Sandwich Islands stand apart zoologically as geographically from the rest of Polynesia, and merit more special attention than has yet been bestowed upon them. Of their Birds, which form the most prominent part of their Vertebrate fauna, Mr. Dole has given a "Synopsis" in the 'Proceedings of the Boston Society of Natural History' (8). In noticing this paper in 'The Ibis' for 1871, I have introduced some supplementary remarks (9) upon the general aspect of the Avifauna.

In concluding this Address, which has extended, I regret to say, to a much greater length than I anticipated when I selected the subject of it, I wish to endeavour to impress upon naturalists the paramount importance of locality.

In the study of distribution more probably than in any other direction, if perhaps we except embryology, will be ultimately found the key to the now much vexed question of the Origin of Species. The past generation of naturalists could not understand the value of locality. A Museum was regarded as a collection of curiosities; and so long as the objects were there it little mattered in their eyes whence they came. The consequence is that all our older collections, and even, I regret to say, our National Museum itself, are filled with specimens utterly without a history attached to them, unless it be that they were purchased of a certain dealer in a certain year. Even in the present generation it is only the more advanced and enlightened thinkers that really understand the importance of locality. It is with the hope of impressing the value of locality and distribution more firmly upon you that I have devoted this address not to the general progress of biology, but to the present state of our knowledge of the Geographical Distribution of the Vertebrata.

APPENDIX.

*List of the Works and Memoirs referred to**.

I. THE PALÆARCTIC REGION.

1. Exploration Scientifique de l'Algérie pendant les années 1840, 1841, 1842. Publiée par Ordre du Gouvernement. Mammifères. Par le Commandant Loche. Oiseaux. Par le Commandant Loche. 2 vols. folio, *Paris*, 1867. Reptiles et des Poissons. Par A. Guichenot. 1 vol. folio, *Paris*, 1850.
2. Catalogue des Mammifères et des Oiseaux de l'Algérie. Par le Capitaine Loche. 8vo, *Paris*, 1858.
3. Nouvelles remarques sur les Poissons fluviatiles de l'Algérie. Par M. Paul Gervais. Comptes Rendus, tome lxiii. (1866) p. 1051.
4. Memoir on the Hydrographical System and the Freshwater Fish of Algeria. By Lieut.-Col. R. L. Playfair and M. Letourneux. Ann. & Mag. Nat. Hist. 1871, viii. p. 373.
5. Essai d'une Erpétologie de l'Algérie. Par Alexandre Strauch. Mém. de l'Académie Impériale des Sciences de St. Pétersbourg, vii^{e} sér. tome iv. No. 7.
6. The Great Sahara: Wanderings South of the Atlas Mountains. By H. B. Tristram. 8vo, *London*, 1860.
7. Five Months' Birds'-nesting in the Eastern Atlas. By Osbert Salvin. Ibis, 1859, pp. 174-191, 302-318, 352-365.
8. On the Ornithology of Northern Africa. By the Rev. H. B. Tristram. Ibis, 1859, pp. 153-162, 277-301, 415-435; 1860, pp. 68-83, 149-165, 361-375.
9. On the Ornithology of Algeria. By J. H. Gurney, jun. Ibis, 1871, pp. 68-86, 289-301.
10. The Ornithology of the Straits of Gibraltar. By Lieut.-Colonel L. Howard L. Irby. 8vo, *London*, 1875.
11. A Journey to Marocco, and Ascent of the Great Atlas. A Lecture delivered before the Birmingham and Midland Institute. By George Maw, F.G.S. &c. 8vo, *Ironbridge*.
12. Histoire naturelle des îles Canaries. Ouvrage publié sous les auspices de M. le Ministre de l'Instruction publique. Par MM. P. B. Webb et S. Berthelot. 4to, *Paris*, 1835-50.

13 *a*. Bemerkungen über die Vögel der Canarischen Inseln. Von Dr. Carl Bolle. Cabanis, Journ. fur Orn. 1854, p. 447; 1855, p. 171.
   b. Mein zweiter Beitrag zur Vogelkunde der Canarischen Inseln. Von Dr. Carl Bolle. Ibid. 1857, p. 258, 305.
   c. Der wilde Canarienvogel, eine Biographie. Von Dr. Carl Bolle. Ibid. 1858, p. 125.

14. A Sketch of Madeira, containing information for the Traveller, or Invalid Visitor. By Edward Vernon Harcourt. 8vo, *London*, 1851.
15. Notice of the Birds of Madeira. By Edward Vernon Harcourt. P. Z. S. 1854, p. 153.
16. Notes on the Ornithology of Madeira. By Edward Vernon Harcourt. Ann. Nat. Hist. xv. 1855, pp. 430-438.
17. Notes on the Resident and Migratory Birds of Madeira and the Canaries. By F. DuCane Godman. Ibis, 1872, pp. 158, 209.
18. A Synopsis of the Fishes of Madeira. By the Rev. R. T. Lowe. Trans. Zool. Soc. ii. p. 173; Supplement, ibid. iii. p. 1.

19 *a*. Descriptions of some new Genera and Species of Fishes obtained at Madeira. By James Yate Johnson, C.M.Z.S. P. Z. S. 1862, p. 167.
   b. Remarks on a specimen of *Alepisaurus ferox* recently obtained at Madeira. By James Yate Johnson, C.M.Z.S. P. Z. S. 1862, p. 126.

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* Nearly the whole of these are in the Library of the Zoological Society of London, and may there be referred to, on application to the Librarian, by Members of the Society and by other persons provided with introductions.—P. L. S.

c. Descriptions of five new Species of Fishes obtained at Madeira. By James Yate Johnson, C.M.Z.S. P. Z. S. 1863, p. 36.

d. Descriptions of three new Genera of Marine Fishes obtained at Madeira. By James Yate Johnson, C.M.Z.S. P. Z. S. 1863, p. 403.

e. Descriptions of a new Genus of Trichiuroid Fishes obtained at Madeira; with remarks on the Genus *Dicrotus,* Gunther, and on some allied Genera of Trichiuridæ. By James Yate Johnson, C.M.Z.S. P. Z. S. 1865, p. 434.

f. Description of *Trachichthys darwinii,* a new Species of Berycoid Fish from Madeira. By James Yate Johnson, C.M.Z.S. P. Z. S. 1866, p. 311.

20. On a New Genus of Pediculate Fish from the Sea of Madeira. By Albert Gunther, M.D., F.R.S., &c. P. Z. S. 1864, p. 301.
21. Natural History of the Azores, or Western Islands. By Frederick DuCane Godman. 8vo, *London,* 1870.
22. Notice sur l'Histoire naturelle des Açores suivie d'une description des Mollusques Terrestres de cet Archipel. Par Arthur Morelet. Roy. 8vo, *Paris,* 1860.
23. Naturgeschichte der Saugethiere Deutschlands und der angrenzenden Lander von Mitteleuropa. Von J. H. Blasius. 8vo, *Braunschweig,* 1857.
24. A Guide to the Quadrupeds and Reptiles of Europe; with Descriptions of all the Species. Compiled from the latest writers. By Lord Clermont. 8vo, *London,* 1859.
25. A History of British Quadrupeds, including the Cetacea. By Thomas Bell. 8vo, *London,* 1837.
26. ——. Second Edition, revised and partly re-written by the Author, assisted by Robert F. Tomes and Edward R. Alston. 8vo, *London,* 1874.
27. Zoologie et Paléontologie Françaises. Nouvelles Recherches sur les Animaux Vertébrés dont on trouve les Ossements enfouis dans le sol de la France et sur leur Comparaison avec les espèces propres aux autres régions du Globe. Par M. Paul Gervais. 2 vols. 4to, *Paris,* 1859.
28. Die Thiere Andalusiens nach dem Resultate einer Reise. Von W. G. Rosenhauer. 8vo, *Erlangen,* 1856.
29. Sketches in Spain during the years 1829–32. By Captain S. E. Cook, R.N. 2 vols. 8vo, *Paris,* 1834
30. Liste des Mammifères et Reptiles observés en Portugal. Par M. Barboza du Bocage. Revue Zoologique, xv. (1863) p. 329.
31. Iconografia della Fauna Italica per le quattro classi degli Animali Vertebrati di Carlo L. Principe Bonaparte. 3 vols. small folio, *Roma,* 1832–41.
32. Fauna del Regno di Napoli, ossia enumerazione di tutti gli animali che abitano le diverse regioni di questo regno e le acque che le bagnano, contenente la descrizione de' nuovi o poco esattamente conosciuti, con figure ricavate da originali viventi e dipinte al naturale di Oronzio-Gabriele Costa. 4to, *Napoli,* 1829–58.
33. Fauna d' Italia. Parte prima. Catalogo Descrittivo dei Mammiferi osservati fino ad ora in Italia, compilato dal Prof. Emilio Cornalia. Roy. 8vo, *Milano.*
34. Faune des Vertébrés de la Suisse. Par Victor Fatio. 8vo, *Genève* et *Bâle,* 1869–72.
35. Expédition scientifique en Morée. Section des Sciences Physiques. Tome iii. 1^{re} partie. Zoologie. Première section des animaux vertébrés. Mammifères et Oiseaux. Par M. Isidore Geoffroy Saint-Hilaire. 4to, *Paris,* 1833.
36. Fauna der Cykladen. Von Erhard. 8vo, *Leipzig,* 1858.
37. Die Insel Cypern, ihrer physischen und organischen Natur nach mit Rücksicht auf ihre frühere Geschichte, geschildert von Dr. F. Unger und Dr. Th. Kotschy. 8vo, *Wien,* 1865.
38. Catalogue Raisonné des Objets de Zoologie recueillis dans un voyage au Caucase et jusqu'aux frontières actuelles de la Perse, entrepris par ordre de S.M. l'Empereur. Par E. Ménétries. 4to, *St. Pétersbourg,* 1832.
39. Voyage dans la Russie méridionale et la Crimée par la Hongrie, la Valachie et la Moldavie, exécuté en 1837. Par M. Anatole de Démidoff. 4 vols. Royal 8vo. and atlas. folio. *Paris.* 1841–42.

40. Skandinavisk Fauna af S. Nilsson. 5 vols. 8vo, *Lund*, 1847–60.
41. Sveriges och Norges Ryggradsdjur, af W. Lilljeborg. 8vo, *Upsala*, ed. *Berling*, 1874.
42. Reisen nach dem Nordpolarmeer in den Jahren 1870 und 1871, von M. Th. von Heuglin. 3 vols. 8vo, *Braunschweig*, 1872–74.
43. Manuel d'Ornithologie ou Tableau systématique des Oiseaux qui se trouvent en Europe; précédé d'une Analyse du Système Général d'Ornithologie, et suivi d'une table alphabétique des espèces; par C. J. Temminck. 2^{e} édition, 4 pts. 8vo, *Paris*, 1820–40.
44. Ornithologie Européenne, ou Catalogue Analytique et Raisonné des Oiseaux observés en Europe, Par C. D. Degland. 2 vols. 8vo, *Paris*, 1849.
45. ——. Deuxième édition, entièrement refondue par C. D. Degland et Z. Gerbe. 2 vols. 8vo, *Paris*, 1867.
46. History of the Birds of Europe, including all the Species inhabiting the Western Palæarctic Region. Parts i.–xvii. by R. Bowdler Sharpe and H. E. Dresser. Parts xvii.–xl. by H. E. Dresser. 4to, *London*, 1871–75 (still being issued).
47. Naturgeschichte der Vogel Europa's. Von Dr. Anton Fritsch. Text, 8vo, atlas, folio, *Prag*, 1870.
48. The Birds of Europe. By John Gould. 5 vols. folio, *London*, 1837.
49. A History of British Birds. By William Yarrell. 3 vols. 8vo, *London*, 1843.
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50. A History of British Birds. By the late William Yarrell. Fourth edition, revised and enlarged by Alfred Newton, M.A. Parts i.–viii. 8vo, *London*, 1871–74 (still being issued).
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52. A Catalogue of the Birds of Northumberland and Durham. By John Hancock. Trans. Northumberland & Durham Nat.-Hist. Soc. vol. vi. (1874).
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54. The Birds of Great Britain. By John Gould, F.R.S., &c. 5 vols. folio, *London*, 1873.
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57. Notes on the Ornithology of Spain. By Lord Lilford. Ibis, 1865, p. 166; 1866, pp. 173, 377.
58 *a*. Ornithological Rambles in Spain. By Howard Saunders. Ibis, 1869, p. 170.
b. Notes on the Ornithology of Italy and Spain. By Howard Saunders. Ibis, 1869, p. 391.
c. A List of the Birds of Southern Spain. By Howard Saunders. Ibis, 1871, pp. 54, 205, 384.
59. Vorläufige Zusammenstellung der Vögel Spaniens mit kritischer Benutzung der bisher von spanischen Ornithologen herausgegebenen Verzeichnisse. Von Dr. A. E. Brehm. Allgemeine deutsche Naturhistorische Zeitung, vol. iii. p. 431.
60. Narrative of a Spring Tour in Portugal. By Rev. Alfred Charles Smith, M.A. 8vo, *London*, 1870.
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69. Des Migrations des Oiseaux de proie sur le Bosphore de Constantinople. Par MM. Amédée Alléon et Jules Vian. Revue Zoologique, tome xxi. (1869) pp. 258, 305, 342, 369, 401; tome xxii. (1870) pp. 81, 129, 161.
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71. Fauna Caspio-Caucasica nonnullis observationibus novis illustravit. Von Dr. Eduard Eichwald. Folio, *Petropoli*, 1841.
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78. Svenska Foglarna, med text af Professor Carl J. Sundevall, tecknade och lithographierade af Peter Åkerlund. Oblong 4to, *Stockholm*, 1856.
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81. Iceland: its Scenes and Sagas. By Sabine Baring-Gould, M.A. Royal 8vo, *London*, 1863. [Appendix A.—Ornithology of Iceland, by Prof. A. Newton, p. 399.]
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86. Our Reptiles. A plain and easy Account of the Lizards, Snakes, Newts, Toads, Frogs, and Tortoises indigenous to Great Britain. By M. C. Cooke. 12mo, *London*, 1865.

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ANATOMY AND PHYSIOLOGY.

Address to the Department of Anatomy and Physiology.

By Professor CLELAND, *M.D., F.R.S., Vice-President of the Section.*

I shall not venture to occupy the time of the Section with any *résumé* of the work done in Anatomy and Physiology during the past year, as such information is readily accessible in the pages of journals and year-books. I shall content myself with making some comments on the condition of Anatomy at the present time in a few important particulars.

I had intended to speak also of some subjects connected with Physiology; but I find that I cannot do so without lengthening my remarks to a greater extent than might be desirable. I shall be content, therefore, so far as that science is concerned, to mention that, although Experimental Physiology is probably less cultivated in this country than in any other in which Biology is studied, it has been practically decided by Parliament that it is quite time to put some check on investigation in that direction; for, as every one knows, a Royal Commission has been appointed to inquire into vivisection. In the scientific world all are agreed, whatever opinions may prevail in other sections of the community, that the man who would wantonly inflict pain on a brute beast is himself a brute, and deserving to be roughly handled; and because there is no difference of opinion on that subject, and because no experimental science can well prosper if one man is to judge for another what experiments are justifiable to institute or to repeat, or are likely to give important results, I do deplore the clamour which well-meaning persons have raised, and regret that it has been so far yielded to.

In Anatomy the most important progress in recent years has been made in those departments which abut most closely on Physiology, namely, the microscopy of the tissues and development. The whole conception of the nutrition of the body has become altered in comparatively recent years by the additions to our knowledge of the nucleated corpuscles, which are the living elements of which it is composed; and principally by the recognition of the secondary nature of cell-walls, the close connexion or even continuity of the nerves with other textures, and the identity of the white corpuscles of the blood with amœboid or undifferentiated corpuscles outside the vessels. The origin of every living corpuscle from corpuscles preexisting is no longer difficult to imagine, but may, I incline to think, be almost looked on as proved. The history of each may be traced back through conjugated germs to the corpuscles of preceding generations in uninterrupted succession, and the pedigree of the structural elements is seen to differ in no way from that of individual plants or animals. It is true, indeed, that no absolute proof exists that new living corpuscles originating by mere deposit are not added to the others; but the evidence against such a thing taking place is exactly of the same description as that which exists against spontaneous generation of independent organisms, namely, that things previously unexplained by the theory of parentage are explained now, while, on the other hand, there is no sufficient evidence of the origin of life by any other mode.

The advance of Histology in recent years is owing in part to the facility of obtaining good microscopes at moderate prices having brought the study within the reach of a great and increasing crowd of observers. At first the progress of Histology was influenced by the steps of improvement in the manufacture of microscopes; but now, for a number of years back, we have been in possession of instruments thoroughly suited for the investigation of tissues; and I think it will be generally admitted that the highest powers which have been manufactured are not those which have advanced discovery most, or are most likely, in the present state of science, to yield the richest harvest. We appear to be more dependent now on new methods of preparation. Thus, if we go back for a considerable number of years, we cannot but remember what a valuable addition glycerine proved when it came first into use, and what a harvest of discovery followed the introduction of chromic acid. More recently, the methods of transparent injection, of preparing sections by imbedding, the freezing of tissues, the use of carmine and other pigments for staining, the resort to metallic depositions by the use of osmic acid, silver and gold, and a variety of other additions to our means of preparation have produced results of an astonishing kind, which have changed the whole aspect of histology from that which it wore when I myself first took an interest in the subject.

Leaving Histology, I shall devote the rest of my remarks to the morphology of the *Vertebrata*. Here I am less disposed to indulge a gratulatory vein. No doubt within the last dozen years we have had work to be grateful for. Worthy of a prominent place in this, as in other departments of anatomy, is the encyclopædic work, the 'Leçons' of Milne-Edwards, invaluable as a treasury of reference to all future observers; while the memoirs of Gegenbaur on the carpus, on the shoulder-girdle, and on the skulls of Selachian fishes, and Kitchen Parker's memoirs devoted to mature forms, may be taken as examples that morphological problems suggested by adult comparative anatomy have not lost their attraction to men capable of elaborate original research. And I the more willingly select the names of these two writers, because on one subject on which they have written, the shoulder-girdle, I am compelled to differ from their conclusions and to adhere rather to those of Owen, so far as the determination of the different elements in fishes is concerned; and by stating this (although the subject cannot be now discussed) I am enabled to illustrate that the appreciation of the value of elaborate and painstaking work is a matter totally distinct from agreement with the conclusions which may be arrived at in the investigation of complicated problems, although wisdom and penetration as to these must ever command admiration.

But when one looks back on the times of Meckel and Cuvier, and on the activity inspired by the speculations of the much-abused Oken, the writings of Geoffroy St.-Hilaire, the less abstrusely speculative part of the works of G. C. Carus, and the careful monographs of many minor writers; when one reflects on the splendid grasp of Johannes Muller, and thinks of the healthy enthusiasm created in this country for a number of years by Owen's 'Archetype and Homologies of the Vertebrate Skeleton,' and then contemplates the state of vertebrate morphology at the present moment, it seems to me that its homological problems and questions of theoretical interest do not attract so much attention as they did, or as they deserve.

There can be no doubt that a great and curious influence has been exercised on morphology by the rise of the doctrine of the origin of species by natural selection. Attention has been thereby directed strongly for a number of years to varieties; and probably it is to this doctrine that we owe the larger number of observations made on variations of muscles, nerves, and other structures. Particularly elaborate have been the records of muscular variations, very praiseworthy, interesting to the recorders, very dry to most other people, and hitherto, so far as I know, barren enough of any general conclusions. So much the more credit is due to those who have worked steadily in faith that beauty will emerge to gild their results some day.

But the doctrine of Natural Selection has had a further effect in anatomical study, aiding the reaction against the search for internal laws or plans regulating the evolution of structures, and directing attention to the modifying influences of external agencies. This effect has happened naturally enough, but it has been far from just; rather is it a pendulum-like swing to another extreme from what had previously been indulged in. The doctrine of natural selection starts with the recognition of an internal formative force which is hereditary; and in the development of the doctrine, the limits of hereditary resemblance have been greatly studied; and further, it will be observed that one of the fundamentals of the doctrine is, that the formative force alters its character gradually and permanently when traced from generation to generation in great tracts of time. Now I am not going to enter on a threadbare discussion of the origin of species in this company; suffice it to say that, while the existence and extensive operation of such a thing as natural selection seems to have been convincingly proved, it is a very different thing to allege that it has been the sole, or even the principal agent in producing the evolutions of living forms on the face of the earth. So far as Anatomy is concerned, it is a secondary matter whether the link between the members of the evolving hosts of life have been genetic or not. But I wish to point out that, even pushing the

Darwinian theory to the utmost possible extreme, the action of external agents infers the existence of something acted on; and the less directly they act, the more importance must be given to the hereditary or internal element. We are therefore presented with a formative force, which exhibited itself in very simple trains of phenomena in the first beginnings of life, and now is manifested in governing the complex growth of the highest forms. We are set face to face with that formative force, and are obliged to admit its inherent capability of changing its action; and that being the case, is it more of an assumption to declare that the changes are all accidental and made permanent by accident of external circumstance, or to consider that it has been the law proper to this force to have been adequate to raise forms, however liable to modification by external circumstances—to raise them, I say, from the simple to the complex, acting through generations on the face of the earth, precisely as it acts in the evolution of a single egg into an adult individual? This is that formative force which has been elaborately shown by Mr. Darwin, in launching his theory of "pangenesis," not only to be conveyed through whole organisms and their seed, but to pervade at all times the minutest particles of each; and I merely direct attention to the fact that its extension over the whole history of life on the globe must be granted, and ask if, in the range of forms which furnish at the present day an imperfect key to the ages which are past, there is not exhibited a development comparable, in its progression to definite goals, with what is shown in the life of a single plant or animal. For my own part, I am fully convinced of a unity of plan running through animal forms, and reaching, so far as the main line is concerned, its completion in the human body. I confess that I think that there is evidence that animal life has reached its preordained climax in humanity; and I cannot think it likely that, as myriads of years roll on, descendants differing *in toto* from man will be developed. To argue the subject would be to enter on the largest subjects of morphological anatomy, and on speculations on which agreement could not be expected. Even, however, in the nature of the variations in the human race there seems to be some evidence that the progress of evolution is to be traced from man, not to other animal forms yet to appear, but, through his psychical nature, into the land of the unseen. Those variations, keeping out of view differences of bulk and stature, which appear to have some relation to geographical position, are principally to be found in the head, the part of the body most closely connected with the development and expression of the mental character; and I may mention that when, some years ago, my attention was directed to the variations of the skull, the only part whose variations in different races I have had opportunity of studying with any degree of minuteness, I became satisfied that in uncivilized races there might be distinguished skulls which had undergone hereditary degeneration, others which had reached the most advanced development possible for them, and a third set, notably the Kaffirs, with large capabilities for improvement in the future. Indeed it is beyond doubt that there is a limit for each type of humanity beyond which it cannot pass in the improvement of the physical organization necessary for mental action*.

There are also some curious indications in human structure of the formative force nearing the end of its journey. In the details of the skeletons of other animals one sees the greatest precision of form; but there are various exceptions to this neatness of finish in the skeleton of man, and they are found in parts specially modified in connexion with the peculiarities of his development, and not requiring exactness of shape for physiological purposes; while, on the other hand, physiognomical mould and nicety of various physiological adaptations are found in perfection. Look at the variations in the breast-bone, especially at its lower extremity, which is never shapely, as it is in the lower animals. Look at the coccygeal vertebræ; they are the most irregular structures imaginable. Even in the sacrum and in the rest of the column the amount of variation finds no parallel in other animals. In the skull, except in some of the lowest forms of humanity, the *dorsum sellæ* is a ragged, warty, deformed, and irregular structure, and it never exhibits the elegance and finish seen in other animals. The curvature of the skull and shortening of its base, which have gradually increased in the ascending series of forms, have reached a degree which cannot be exceeded; and the nasal cavity is so elongated vertically, that in the higher races nature seems scarcely able to bridge the gap from the cribriform plate to the palate, and produces such a set of unsymmetrical and rugged performances as is quite peculiar to man; and to the human anatomist many other examples of similar phenomena will occur.

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* I allude to the circumstances—that under the influence of civilization the length of the base of the skull does not increase, but positively decreases; that the proportion of the extent of the arch to the base has strict limits; that the curvature of the base in some uncivilized races falls slightly short of the normal; that in others it transcends the normal by a peculiar process of degeneration between the sphenoid and ethmoid; and that increased capacity of the cranial cavity in the progress of civilization is obtained almost entirely by increase of breadth and by the rounding out of those flat surfaces above and below the temporal ridges which give savage skulls a roof-like appearance. (See "Inquiry into Variations of Skull," Phil. Trans. 1870.)

Questions of homology are matters which must be ever present in the study of structure, as distinct from function—both the correspondence of parts in one species to those in others, and the relations of one part to another in the same animal; and perhaps I shall best direct attention to the changes of opinion on morphological subjects in this country during the last twenty-five years by referring shortly to the homological writings of three eminent anatomists—Professors Owen, Goodsir, and Huxley.

For the first time in English literature the great problems of this description were dealt with in Professor Owen's work already referred to, published in 1848; and it is unnecessary to say that, notwithstanding the presence of unquestionable errors of theory, that work was a most valuable and important contribution to science. The faults in its general scope were justly and quietly corrected by Goodsir at the Meeting of this Association in 1856 in three papers, one of them highly elaborate; and in these he showed that the morphology of vertebrate animals could not be correctly studied while reference was made exclusively to the skeleton. He showed the necessity of attending to all the evidence in trying to exhibit the underlying laws of structure, and especially of having constant regard to the teachings of embryology. Among the matters of detail which he set right it may be mentioned that he exposed the untenability of Professor Owen's theory of the connexion of the shoulder-girdle with the occipital bone, and pointed out that the limbs were not appendages of single segments corresponding with individual vertebræ. Referring to the development of the hand and foot, he showed the importance of observing the plane in which they first appear, and that the thumb and great toe are originally turned toward the head, the little finger and little toe toward the caudal end of the vertebral column. But he probably went too far in trying to make out an exact correspondence of individual digits with individual vertebral segments, failing to appreciate that the segmentation originally so distinct in the primordial vertebræ becomes altered as the surface of the body is approached—a truth illustrated in the vertebral columns of the plagiostomatous fishes, in the muscle-segments over the head in the pleuronectids, and in the interspinal bones bearing the dorsal and anal fin-rays of numbers of fishes, but, so far as I know, not hitherto sufficiently appreciated by any anatomist.

Goodsir also exploded, one would have thought for ever, the erroneous theory of the correspondence of the mammalian tympanic plate with the quadrate bone of birds and the suspensorium of fishes, directing attention to the neglected but just appreciation by St.-Hilaire of the homological importance of the ossicles of the ear, and to the embryological work of Meckel and Reichert. But undoubtedly he fell into great mistakes of his own in matters of detail connected with the exceedingly difficult question of the correspondence of the bones of the skull, the principal of these probably being an unfortunate notion that the *great frontal* of fishes was a bone which disappeared from the skulls of mammals, a notion which spread its influence over his determination of a number of other elements, and introduced a confusion which made his paper on the skull hard to understand.

In 1858 Professor Huxley delivered his Croonian Lecture on the vertebrate skull, and in 1863 his lectures at the Royal College of Surgeons on the same subject. He profited by the wisdom of Goodsir, and studied the works of Rathke, Reichert, and other embryologists. But, rightly or wrongly, he took a step further than Goodsir. He assumed from the first that the homologies of adult structures could be determined by development, and that by that study alone could they be finally demonstrated. As regards the skull, the constitution of which always remains the central study of the vertebrate skeleton, his writings marked the introduction of a period of revulsion against not only the systems of serial homologies previously suggested, but even against any attempt by the study of the varieties of adult forms to set them right. Mr. Huxley has added materially to the previously existing number of interpretations as to what elements correspond in different animals, and in doing so has found it necessary to make various additions to the already troubled nomenclature. Those who consider these changes correct will of course see in them a prospect of simplicity to future students; but to those who, like myself, have never been able to agree with them, they are naturally a source of sorrow. Among the changes referred to may be mentioned the theory of the "*periotic bones.*" That theory I venture to think a very unfortunate one, introducing a derangement of relations as wide spread as did Goodsir's theory of the frontal bone. And do not think me presumptuous in saying so, seeing that this theory is in antagonism with the identifications of every anatomist preceding its distinguished originator, not excepting Cuvier and Owen; nor is it easy to discover what evidence it has to support it against the previously received decision of Cuvier as to the *external occipital* and *mastoid* of fishes. Without entering into the full evidence of the subject; it may be stated that, so far as this theory affects the *alisphenoid* in the skull of the fish, it must be given up, and the determination of Professor Owen must be reverted to, when it is considered that in the carp the third and fourth nerves pierce what that anatomist terms the *orbitosphenoid*, the bone which is *alisphenoid* according to the theory which terms the *alisphenoid* of Owen the *prootic*. A proof still more striking is furnished by *Malapterurus* and other Silurids, in which the bone in question is pierced by the optic nerve. That being the case, the prootic theory will be seen to have arisen partly from giving too much importance to centres of ossification, and partly from considering the nerve-passage in front of the main bar of the *alisphenoid* of Owen as corresponding with the *foramen ovale* of man rather than with the *foramen rotundum* and sphenoidal fissure. A spiculum, however, separating the second from the third division of the fifth nerve, and having therefore the precise relations of the mammalian *alisphenoid*, does exist in the carp and other fishes. But in reptiles Professor Huxley's determination of the *alisphenoid* is right, and Professor Owen's clearly wrong; for in the crocodile the *alisphenoid* of Huxley and others is perforated by the sixth nerve, so that it cannot have any claim to be called *orbitosphenoid*. I must, however, maintain against Prof. Huxley's view Prof. Owen's determination of the *nasal* in fishes, notwithstanding that Prof. Owen has failed to appreciate the exact relation of that bone to the nasals of mammals, and has thereby laid his position open to attack. The arguments on that point Prof. Huxley was good enough to lay before the public fourteen years ago, by kindly reading for me before the Royal Society a paper which subsequently appeared in its 'Transactions;' and I am not aware that any one has since attempted to controvert them.

I shall not trouble you further with such matters of detail; but it will be clear from what has been said that the beginner in comparative anatomy must at the present day find himself at the outset, in the most important part of his osteological studies, faced with a diversity of opinion and confusion of nomenclature sufficient to produce much difficulty and to have a repelling effect on many minds. Such difficulties might well be encountered with enthusiasm where a belief existed that behind them lay a scheme of order and beauty; but not many will spend time investigating such intricate details if they doubt the interest of the general conclusions likely to be reached by mastering them. On this account it is a great pity that the scepticism generated partly by the difficulties of the subject, and partly by reaction from the dogmatism of the admirers of Oken, does too frequently discourage the investigation of the serial homologies of the parts entering into the segments of the skull, and the determination of the nature and number of those segments. It is a pity that so much clamour has been made for a number of years against the expression "vertebral theory of the skull," because fighting against words is but stupid warfare at the best, and because all that was really meant, and that could be justly stated, could have been brought into prominence without objecting to a time-honoured phrase. It is questionable if any one who ever used the convenient term "vertebral theory" meant to indicate more than a certain community of plan on which were built the segments of the skull as well as those of the spinal column; that, in fact, the two constituted one complete chain, of which the first few segments were so different from the rest that, till Oken pointed the fact out, it was not recognized that they were segments lying in lineal continuity with the rest. But the matter has recently stood thus:—that to some minds, in the imperfect state of our knowledge, one thing seemed essential to a segment comparable with the rest, and to others something else seemed requisite; and the oddity of the position of affairs is this, that the objectors to the phrase "vertebral theory" have been as crotchety in setting up imaginary essentials to a segment as their neighbours. On the one side we were taught to expect certain definite osseous elements in each segment, to which definite names were given; while, on the other, in opposition schemes, centres of ossification have been built on as matters of primary consequence, although a glance at the modifications in the vertebral column proper might convince any one that they are things of the very slightest importance morphologically. Also those who have objected to speaking of cranial vertebræ have put great importance on the point at which the *chorda dorsalis* terminates, although it has been long known that in one animal the *chorda dorsalis* runs right on to the front, that in others it fails to enter the skull at all, while in the majority it passes for a certain distance into the base. Johannes Müller, on such grounds, concluded, thirty years ago, that the presence of *chorda dorsalis* was not necessary to constitute a cranial vertebra; and there seems no reason to doubt that he was right. Looking at the early embryo, the cerebro-spinal axis is seen to be one continuous structure; and the walls of the canal containing it are likewise manifestly continuous, not at first distinguishable into a spinal and a cranial portion. Looking at the adult condition, in the higher classes the vertebræ of the tail are seen dwindling into mere bodies developed round the *chorda dorsalis*, and giving off rudimentary processes without separate centres of ossification, while towards the head the bodies diminish and the arches enlarge; and in the skull the *chorda*, round which the bodies in the rest of the column are developed, comes to an end, and the neural arches are enormously enlarged and have additional centres of ossification, precisely as in the mammalian thorax costal centres of ossification are found which do not exist in the costal elements of cervical vertebræ. It would therefore be quite as justifiable to object to the term vertebra as applied to a joint of the tail because it has no *laminæ*, or none with separate centres of ossification, as to object to its applicability to segments of the skull because the *chorda* is absent, or the osseous elements different in number from those found usually in the segments of the trunk.

However, it is gratifying to observe that among the most recent additions to morphological anatomy there is a highly suggestive paper by Professor Huxley, appearing in the Royal Society's 'Proceedings' for December last, and entitled "Preliminary Notes upon the Brain and Skull of *Amphioxus lanceolatus*," in which the learned Professor, who has for many years been the most determined opponent to the mention of cranial vertebræ, declares, so far as I can apprehend his meaning, that the region of the head represents no less than fourteen segments, all of which he terms *protovertebræ* in *Amphioxus*. This determination of correspondences is made the more remarkable by being followed up with a suggestion that the numerous protovertebræ lying in front of the fourteenth in *Amphioxus* are represented only by muscles and nerves in the higher vertebrates.

I hail this paper as being practically at last an ample acknowledgment that there is no escape from admitting the correspondence of the region of the head with the segments of the trunk: but the details of the new theory scarcely seem convincing; and I might have preferred to leave its discussion to others, were it not that the notions which it opens up are far too important to allow it to be passed over in any account of the present state of opinion on the subject of vertebrate morphology. The argument in this new theory runs thus: that the palate-curtain of *Amphioxus* is homologous with that of the lamprey, and that the palate-curtain of the lamprey is attached below the ear; that therefore all the seven segments seen in front of the palate-curtain of *Amphioxus* are represented by parts in front of the ear in the lamprey and the other Vertebrata. Again, the branchial arches of the higher Vertebrata are assumed to be of the nature of ribs, and in none of the Vertebrata next above *Amphioxus* "are there more than seven pairs of branchial arches, so that not more than eight myotomes (and consequently protovertebræ) of *Amphioxus*, in addition to those already mentioned, can be reckoned as the equivalents of the parachordal region of the skull in the higher vertebrates." Every thing, observe, depends on the segment to which the palate-curtain of *Amphioxus* belongs. Now I have already pointed out to you that the segmentation of the vertebrate body is not perfect; and there is no method by which the alimentary canal, of which the mouth and palate are the first part, can be divided into segments corresponding with the cerebro-spinal nerves. Most certainly we cannot judge that a portion of a viscus belongs to a particular segment from its lying underneath some other structure in definite relation, like the ear, to the cerebro-spinal system; for then should we be obliged to grant that one half or more of the heart belongs to segments in front of the ear, since it is undoubtedly so situated in a chick of the thirty-sixth hour. But the branchial arches are in front of the heart, and, according to the theory which we are considering, are behind the ear; thus the principle assumed in the starting-point of the theory is taken away.

Again, it is important to observe that the branchial skeletal arches cannot be ribs, for they lie internal to the primary circles of the vascular system formed by the branchial arteries and veins, while the ribs are superficial to both heart and aorta. If the ribs are represented at all in the branchial apparatus (and I doubt it very much), it is by the cartilages superficial to the gills in sharks, rays, and dogfishes; and it would seem impossible for any one who has dissected them to doubt that those cartilages are homologous with the branchial skeleton of the lamprey, which they somewhat resemble. In fact if the external and internal branchial openings of the lamprey be enlarged, its gills are reduced to a form similar to those of the shark.

There is nothing in this, however, which interferes seriously with the proposed theory of the skull. It is merely a point in the argument which I have thought right to clear. More important it is to remark that, on the supposition that numerous protovertebræ are represented in the region of the head, there are most serious difficulties interfering with the idea that they are, as Professor Huxley states, "represented only by muscles and nerves in the higher Vertebrata," and that there is any correspondence between "the oculo-motor, pathetic, trigeminal, and abducens nerves with the muscles of the eye and jaws" and the regular nerves and muscle-segments of the fore part of *Amphioxus*. Even in the lamprey the eyeballs are supplied with muscles similar to those to which, in other vertebrates, the oculo-motor, pathetic, and abducens are distributed; and I find in the large species that, notwithstanding this, the series of regular muscle-segments is continued over the head, not indeed in the same way as in *Mixine*, but in a highly instructive and curious manner. The five foremost muscle-segments have their upper extremities attached considerably in front of the nasal opening by a short tendon, which touches its fellow in the middle line; and extending thence in an outward and backward direction they pass behind the eyeballs, the first two running in front of the first gill-pouch, and the third lying over it. Therefore, in this instance, as surely as the nostril is in front of the eye, so surely the upper extremities of these muscle-segments are shifted forwards out of their morphological place, probably in connexion with the great protrusion of the jaws for the physiological purpose of forming a sucker. There is no escape from granting this shifting, even were it possible to believe that the eyeball could be further forward than the nostril; for while the fifth muscle-segment can be traced in front of the nostril, the sixth occupies the interspace between the skull and first vertebra, so that if the muscle-segments are taken as a guide, the whole skull, forward to the nostril, belongs to one intersegmental space, a view which is clearly absurd. The succeeding inter-muscular septa correspond each with a cartilaginous vertebral arch; and it is interesting to observe that the branchial cartilages are not placed one for each septum, like the fibrous representatives of ribs detectable within the septa; for the second cartilage is opposite the sixth septum, the third opposite the ninth, the fourth opposite the eleventh, the fifth opposite the thirteenth, and the sixth and seventh opposite the fourteenth and fifteenth septa; and this is one reason for doubting that even these superficial branchial cartilages, though attached to the vertebral column, are to be regarded as ribs.

It may be noticed as a wholesome symptom in anatomical speculation, that the new theory which has led to these remarks is founded on arguments drawn altogether from comparison of different species, and not from embryology, a very remarkable circumstance as coming from one who so lately as last autumn reiterated in this Section his slowness to believe in reasonings founded on adult forms, and even on "later development." The wisest know so little, that humanity must be content to gather information from every possible source, and leave no set of ascertained facts out of view in attempting to arrive at generalizations. If we had before us all the adult anatomy of every species that ever lived on the earth, we should only then have the record completed from which to frame a full system of morphology; and as matters stand we must translate embryological phenomena with the aid of the series of adult forms, as well as translate the teachings of the adult series with the aid of embryology.

Falling back on my proposition, that the segments of the vertebrate body are nowhere complete, and that segmentation at one depth may exist to a greater extent than at another, I may mention certain embryological phenomena in the brain, which have received too little attention, and which to some extent warrant belief in a larger number of segments in the head than is usually admitted; although I do not see that they are necessarily at variance with that theory of seven segments in every ossified skull which I indicated in 1862. In the chick, in the middle of the second day of hatching, already is the third cerebral vesicle divided into a series of five parts, separated by slight constrictions, the first part larger than those which succeed, and the last part narrowing to the spinal cord. The auditory vesicle lies opposite the constriction between the fourth and fifth parts. At the end of the second day and during the third, these divisions assume dimensions which give them a general appearance exceedingly similar in profile to the protovertebræ of the neck. In the following day they exhibit a more complex appearance, and after that the first compartment alone remains distinct as cerebellum, while the divisions between the others disappear in the thickening of the cerebral walls. In their first two stages, Mr. Huxley, whom I have already referred to so often, has figured these crenations, but he has not, so far as I know, described them.

I may also direct attention to another embryological point, to which I referred last year at Belfast as a probability. I speak now from observation. That which is termed the first cerebral vesicle in the early part of the second day of hatching of the chick, is an undifferentiated region of the brain from which a number of parts emerge successively from behind forwards. As early as the thirty-sixth hour the optic nerves can be traced, separated from the rest of the vesicle by distinct elevations of the floor of the brain, reaching inwards to the constriction between the first and second vesicles: and as early as this date the first trace of bifidity of the brain in front may be discerned—that bifidity which, to my thinking, is only one of several instances of longitudinal fission in the fore part of the head, the trabeculæ presenting another instance of the same thing, and the cleft between the maxillary lobe and the part of the head above it a third; while in the muscular system such longitudinal cleavage or fission is common even in the trunk. In a chick of the third or fourth day, when rendered very transparent, the optic nerves can be seen extending from beneath the front of the optic lobes; while in front of the optic lobes there are placed in series from behind forwards a posterior division of the first vesicle, an anterior division, the cerebral hemispheres, and the olfactory lobes. Thus there is a large supply of material presented in the brain for the study of segmentation; the difficulty to be overcome by future inquiry and careful collation of all available facts is to determine the value of the parts placed one in front of another.

Perhaps I have occupied time too long with matters involving a large amount of technical detail; but I trust that I may have, in some measure, illustrated that both in aim and in accomplished work Anatomy is no mere collection of disconnected facts, no mere handmaid of the physician and surgeon, nor even of Physiology. I do not doubt that it is yet destined, as dealing with the most complex sequences of phenomena, to take the highest place among the sciences as a guide to Philosophy. One cannot help noticing the increased importance now given to Natural-History studies as a part of education; and it is worth while to note that it is most of all in Anatomy and Physiology that the close connexions of matter with mind are brought under review,—Physiology exhibiting the relations of our own mental being to our bodies, and Anatomy revealing a body of organized Nature, whose organization points to a source of beauty and order beyond.

The people of Bristol do well to rally round their Medical School. They do well to furnish it with buildings suitable for the prosecution of all the Natural-History studies which adhere to medical education; and they do well to join with that school a complete College of literature and science. Let us hope that they will make it worthy of so wealthy and historic a city. But if they will have their medical school the success which in so flourishing a locality public enthusiasm may well make it, and if they will have it aid as well as be aided by a school of general education, let them follow the system latterly adopted in Oxford and Cambridge, long carried out in the Universities of Scotland, and recognized, though not in all instances sufficiently provided for, in Ireland. Let Anatomy, human and comparative, receive its place as an important and fundamental science. Let thorough and adequate provision be made for its being taught as a science; and see that it do not, as in too many medical schools which shall be nameless, degenerate to the etymological and original meaning of the word, a mere cutting up of carcasses.

ANTHROPOLOGY.

Address to the Department of Anthropology. By GEORGE ROLLESTON, *M.D., F.R.S., F.S.A., Linacre Professor of Anatomy and Physiology, Oxford, Vice-President of the Section.*

Some few weeks ago Mr. James Parker, of Oxford, invited me to visit your Somersetshire caves, in the company of the Warwickshire Naturalists' and Archæologists' Field Club. It struck me that I should do well, as I was to preside over the Anthropological Department at this British-Association Meeting, if I tried to learn as much as I could of the relics and of the surroundings of the Prehistoric inhabitants of your neighbourhood; and for this, as well as for other reasons, I gladly accepted the invitation. During that pleasant midsummer excursion I was more than once impressed with the similarity which its incidents bore to those of the undertaking in which we are now engaged, and, indeed, to those of the study of Anthropology generally. First, the organization of the expedition had entailed some considerable amount of labour upon those who had charged themselves with that duty; and, secondly, a thorough exploration of the recesses and sinuosities of the several caves which we explored devolved upon us not only a good deal of exertion, but even some slight amount of risk; for the passages and galleries along which we worked our way were sometimes low and narrow, often steep, and nearly always slippery. Thirdly, the outline of the regions explored bore quite different aspects accordingly as we lighted them up or had them lit up for us in one or in another of several different ways.

If in any segment of these caves the outside daylight could anyhow find a zigzag way down some shaft into the interior, that segment wore a general aspect more comfortable to the eye, and so to the mind, than others not so illuminated. These latter regions again varied greatly *inter se*, according to the various artificial means employed for lighting them up. The means ordinarily used for this end made their outlines look a little colder and harder than the reality itself, cold and hard though this was; whilst under certain other modes of illumination employed (it is true, only occasionally, and for purposes of effect, not *ex necessitate*) the self-same outlines looked somewhat lurid. But, howsoever produced and howsoever affecting us, the light was light nevertheless, and, on the whole, we preferred it a good deal to the darkness. It is never well to press a metaphor too far nor too closely; so I will now lay aside my parable, though it admits of some further extension, and take up the actual business of the Department.

It may be well to lay before the Department, first of all, the titles of a few of the principal subjects upon which we have papers prepared for us; and after, or indeed during the enumeration of these specimens of what will prove, I can assure you, a very valuable series of memoirs, we can proceed, as will be naturally suggested, to those general considerations with which it is customary to open the transactions of such assemblages as ours.

First among our contributors I must mention the President of the London Anthropological Institute, in which Institute the Ethnological Society of 1844 and the Anthropological Society of 1863 are united. Colonel Lane Fox has told us (Archæologia, xlii. p. 45, 1869) that it was whilst serving on the Subcommittee of Small Arms in 1851 that he had his attention drawn to the principle of continuity by observing the very slow gradations of progress that were taking place at that time in the military weapons of our own country. Out of those labours of his on that Subcommittee other benefits have arisen to the country at large, of which it is not my province to speak. What I have to speak of is his suggestion, put out with greater definiteness in his invaluable Lecture on Primitive Warfare, delivered before the United-Service Institution, June 5, 1868 (p. 15), to the effect that his find at Cissbury furnishes the links which were wanting to connect the Palæolithic with the Neolithic Celt types. Sir John Lubbock* and Mr. Evans† have told us that they do not see their way towards accepting this view; and Mr. James Geikie, who holds that the palæolithic deposits are of preglacial and interglacial age, is almost necessitated, *ex hypothesi*, to repudiate any such transition. He does so (pp. 436–438 of his work on the Great Ice Age) in language which shows us that Colonel Lane Fox's lecture just referred to, with its diagram No. 1 (printed, it is true, for private circulation), could not have met his eye. Colonel Lane Fox's paper will relate to further explorations carried on at Cissbury during the present year by a Committee of the Anthropological Institute with the kind permission of Major Wisden, the owner of the soil. It will raise more than one large question for us to address ourselves to. I shall, when Colonel Lane Fox's paper comes before the Department, contribute towards its discussion by showing a number of flints from Cissbury, given me by my friend Mr. Ballard, of Broadwater.

Mr. Pengelly will, on Monday, give us an account of the "Anthropological Discoveries in Kent's Cavern." A more interesting subject will not often have been treated in a more interesting manner.

Polynesia and Australasia generally have always been an interesting field for the anthropologist. Our recent acquisition of Fiji makes it doubly interesting to us just now; and a flood of literature has burst forth upon us to meet that interest.

Professor Dr. Carl E. Meinicke is to be heartily congratulated on having, in the present year, brought out a work on the islands of the Pacific ('Die Inseln der Stillen Oceans, eine geographische Monographie.' Erster Theil, Melanesien und Neuseeland. Leipzig, 1875), in which he can, with not unbecoming pride, say that he is still working upon the same principles which guided him nearly fifty years ago in the composition of his works on the continent of Australia and the South-Sea races. Though I possess Professor Meinicke's works, I am not as yet entirely in possession of all his views; but so far as I can see, they are well worthy of attention. I do not hesitate, however, at all in saying that the most important contribution to the ethnology of Polynesia which has been made recently is the article on that subject in the 'Contemporary Review' for February 1873, by the Rev. S. Whitmee, of Samoa. And I may say that I am not without hopes that we shall be favoured with some papers upon the ethnology, anthropology, and future prospects of the Polynesian race by other persons eminently qualified to speak upon the subject, as having spent many years usefully among them, and on the spot. I observe that writers who have little respect for most things else, and by no means too much for themselves, speak still with something like appreciation of the work done in those regions by the London Missionary Society; and we here shall value highly any papers which we may be favoured with from men who have had such long and such favourable opportunities for forming opinions on matters which touch at once our national and our scientific responsibilities.

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* Nilsson's 'Primitive Scandinavia,' Editor's Introd. p. 24.

† 'Flint Implements,' p. 72.

What question can be of closer concernment than that of the possibility of rescuing the inhabitants of Polynesia from that gradual sliding into extinction which some writers appear to acquiesce in as the natural fate of such races. As a text for our discussions upon this subject, I will here quote to the Department a passage from the continuation of Waitz's 'Anthropologie' by Dr. Gerland—the author, be it remembered, of a special Monograph upon the Causes of the Decrease and Dying-out of Native Races, which appeared in 1868 ('Ueber das Aussterben der Naturvolker,' Leipzig), and has been often referred to by writers on anthropology since that year, and is referred to by himself in the passage I now lay before you. It runs thus ('Anthropologie der Naturvölker,' von Dr. Theodor Waitz, fortgesetzt von Dr. Georg Gerland, 1872, vol. ii. pp. 512, 513):—

"The decrease of the Polynesian populations is not now going on as fast as it was in the first half of the century; it has in some localities entirely ceased, whilst in others the indigenous population is actually on the increase *. From this it is clear that the causes for that disappearance of the native races which we discussed at length in the little book above referred to, are now less or no longer operative. For, on the one hand, the natives have adapted themselves more to the influences of civilization; they are not so amenable as they were at first to the action of diseases, although we still from time to time have instances to the contrary at the present moment (see, for example, Ev. Miss. Mag. 1867, p. 300, Cheever, 295) [or, I may add, our own recent information as to the destructive outbreak of measles in Fiji]; they have become more able to respond to the efforts to raise their mental and moral status than they were; and, with the advance of civilization, they have begun to avail themselves more of the remedial agencies which it brings with it. On the other hand, we cannot ignore the fact that the Europeans themselves, in spite of many important exceptions, have nevertheless done a very great deal for the natives, and are always doing more and more for them. Whilst in this matter the English Government deserves great praise, and whilst Sir George Grey has done more for the Polynesians than almost any other man, the missionaries nevertheless stand in the very first rank amongst the benefactors of these races, with their unwearied self-sacrificing activity; and Russel ('Polynesia,' Edinb., 1840) is entirely right in saying that all the progress which the Polynesians have made was really set on foot by the missionaries. They have had the greatest influence upon the civilization of the natives; they have taken their part and protected them when they could; they have further given them the fast foothold, the new fresh object, motive, and meaning for their whole existence, of which they stood so much in need. The Polynesians have often declared to the missionaries, 'If you had not come, we should have perished;' and they would have perished if their country had not been so discovered. The resources of their physical life were exhausted; and they had none of the moral nor ideal support for the needs of their spiritual nature which they stood so urgently in need of, as they had already attained a grade of culture too high to allow of their living without some support of that kind. It is true that extraneous circumstances have often, especially in the outset, brought about their conversion—as, for example, the authority of their chiefs, the force of example, as also, on the other hand, the occurrence of misfortune, great mortality, the loss of a battle, after which they wished to make the experiment of worshipping a new god (Russel, pp. 386, 390). And it is also true that the missionaries have introduced them to an exceedingly bigotted and often little-elevated form of Christianity; but even this has been a fortunate circumstance; for just the comprehensi-

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* See 'Times' of last Saturday, August 21, 1875, p. 6, where the Natal correspondent, writing of the Caffres, tells us, "we shall have to begin civilizing the natives some day. We had better have begun with them ten years ago at 200,000 strong, than now at 350,000; but we had better begin with them now at 350,000 than ten years hence when they may number half-a-million." Since writing as above I have received through my friend the Rev. W. Wyatt Gill a long extract from a paper written in 1861, by the Rev. A. W. Murray. This paper fully confirms Gerland's more recent views as to the prospects of the native races. Mr. Murray, having spent forty years in Polynesia, has the best possible right to be heard upon it.

ility, the plain appeal to the senses, of this new religion took hold of the imagination f these races, and they could take hold of it with their understanding; and however it may have been put before them, it was immeasurably above the level of eathenism, and considerably above that of Mahommedanism. Whatever the ogmas taught were, the ethics of Christianity were taught with them; and in ost cases the missionaries gave, at the same time, in their lives striking examples f the value of those ethics; and the fact of their maintenance and exemplification vas the main thing.”

Mr. Bagehot has been quoted by Mr. Darwin, in his ‘Descent of Man,’ ed. 1, ol. i. p. 239, ed. 2, p. 182, as saying that “it is a curious fact that savages did not ormerly waste away before the classical nations, as they do now before the modern ivilized nations; had they done so the old moralists would have mused over the vent; but there is no lament in any writer of that period over the perishing bar-arians.” On reading this for the first, and indeed for a second time, I was much mpressed with its beauty and originality; but beauty and originality do not im-ress men permanently unless they be coupled with certain other qualities. And I vish to remark upon this statement, first, that it is exceedingly unsafe to argue rom the silence of any writer, ancient or modern, to the non-existence of the non-entioned thing. I do not recollect any mention in the ancient writers of Stone-enge, nor can I call to mind at this moment any catalogue of the vocabularies of he Cimbri and Teutones, of the Ligures and Iberians, with whom the ancients were rought into prolonged contact. These little omissions are much to be regretted, as, f they had been filled up, a great many very interesting problems would thus have een settled for us which we have not as yet settled for ourselves. But these omis-ions do not justify us in thinking that Stonehenge is an erection of post-Roman imes, nor in holding that any of the strange races mentioned were devoid of a anguage. But, secondly, what we know of the classical nations dates from a time vhen the “merciless bronze” had begun to give way to the “dark gleaming” steel. ut long before the displacement of bronze weapons by iron ones, the bronze had ad abundant time to displace both stone weapons and the people who used them. nd it is plain enough to suggest that one reason why the old moralists did not nuse over the disappearance of the aboriginal races lies in the fact that these races ad neither a contemporary Homer to sing their history, nor an Evans to interpret heir weapons after their extinction. The actual Homeric poems deal with a region hickly peopled and long subdued by a Greek-speaking metal-using race. Rhodes nd Crete were as different then from what Fiji and New Guinea are now, as Me-ion and Idomeneus are from Thakombau and Rauparahu. But, thirdly, let us ask, s the philosophers did with regard to the fish and its weight in and out of the ucket of water, Are the facts about which we are to inquire really facts? Now I m not going to plunge into the excursuses appended to editions of Herodotus, nor o discuss the history of the Minyæ, or of any other race of which we know as ittle. But I will just quote a few verses from a beautiful passage in Job which ppear to me to give as exact a description of a barbarous race perishing and out-ast, as could be given now by a poetical observer in Australia or California. peaking of such a race the poet says:—

“For want and famine they were solitary, fleeing into the wilderness in former ime desolate and waste. Who cut up mallows by the bushes, and juniper roots or their meat. They were driven forth from among men, (they cried after them as fter a thief;) To dwell in the cliffs of the valleys, in caves of the earth, and in the ocks. Among the bushes they brayed; under the nettles they were gathered to-ether. They were children of fools, yea, children of base men; they were viler han the earth” (Job, chap. xxx. ver. 3–8).

I opine that these unhappy savages must have “wasted away” under these con-itions, and that there is no need, with such actual *veræ caussæ* at hand, to postu-ate the working of any “mysterious” agency, any inscrutable poisonous action “of he breath of” civilization. What is mysterious to me is not civilization, but the act that people who are in relation with it do not act up to its behests. And what s the mystery to me is not how an epidemic can, when introduced amongst helpless Polynesians, work havoc, but how it is that epidemics should be allowed to do so ere in England from time to time. We are but some four years away from the last small-pox epidemic, of the management, or rather mismanagement, of which I had myself some little opportunity of taking stock; and what we saw then in England renders it a little superfluous to search for recondite causes to account for depopulation in countries without Local Boards. You owe much in Bristol to your able, energetic, and eminently successful officer of health, Dr. David Davies. I hope he may favour us with his views upon this very interesting subject, and may, knowing, as he well does, how much energy and knowledge are required for the reduction of a rate of mortality, tell us how much wickedness, perversity, and ignorance are necessary for increasing such a rate, whether in Great or in Greater Britain. I think that he will tell us that what is mysterious is not the power of the principles of action I have just mentioned, but the toleration of them. Such, at least, are my views*.

We have several philological papers promised us. Amongst them will be one by the Rev. John Earle, who is known to you in this neighbourhood as living near Bath, and who is known to people not so pleasantly situated on the earth's surface as you are, as the author of a Handbook of the English tongue. I shall, as he will be present hereafter to speak on philology, spare myself and you the trouble of any remarks on that truly natural science, observing merely that Dr. Farrar † and Professor Hackel ‡ are both agreed upon one point, namely that the adoption of natural-history methods by the students of languages has opened up for them a fresh career of importance and interest and usefulness.

Somersetshire is not without its historian; and the possibility of his coming renders it unadvisable for me to say any thing now as to the relation of history to our subject upon the present occasion. If, however, the Department can find time to listen to me a second time, I shall be glad to read a short paper myself upon this very subject, mainly in the hope of getting Mr. Freeman to speak upon it also.

I come now (perhaps I should have come before) to the consideration of the subject of craniology and craniography. Of the value of the entirety of the physical history of a race there is no question; but two very widely opposed views exist as to the value of skull-measuring to the ethnographer. According to the views of one school, craniography and ethnography are all but convertible terms; another set of teachers insist upon the great width of the limits within which normal human crania from one and the same race may oscillate, and upon the small value which, under such circumstances, we can attach to differences expressed in tenths of inches or even of centimetres. As usual, the truth will not be found to lie in either extreme view. For the proper performance of a craniographic estimation, two very different processes are necessary: one is the carrying out and recording a number of measurements; the other is the artistic appreciation of the general impressions as to contour and type which the survey of a series of skulls produce upon one. I have often thought that the work of conducting an examination for a scholarship or fellowship is very similarly dependent, when it is properly carried out, upon the employment of two methods—one being the system of marking, the other that of getting a general impression as to the power of the several candidates; and I would wish to be understood to mean by this illustration not only that the two lines of inquiry are both dependent upon the combination and counterchecking of two different methods, but also that their results, like the results of some other human investigations, must not be always, even though they may be sometimes, considered to be free from all and any need for qualification. Persons like M. Broca and Professor Aeby, who have carried out the most extensive series of measurements, are not the persons who express themselves in the strongest language as to craniography being the universal solvent in ethnography or anthropology. Aeby, for example, in his 'Schadelformen der Menschen und der Affen,' 1867, p. 61, says:—"Aus dem gesagten geht hervor, dass die Stellung der Anthropologie gegenüber den Schadelformen eine ausserordentlich schwierige ist;" and the perpetual contradiction of the results of the skull-measurements carried out by others, which his paper (published in last year's 'Archiv fur Anthropologie,' pp. 12, 14, 20) abounds in, furnishes a practical commentary upon the just quoted words. And Broca's words are especially worth quoting, from the 'Bulletin de la Société d'Anthropologie de Paris,' Nov. 6, 1873, p. 824:—"Dans l'état actuel de nos connaissances la craniologie ne peut avoir la pretention de voler de ses propres ailes, et de substituer ses diagnostics aux notions fournies par l'ethnologie et par l'archéologie."

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* Since I wrote as above, we have received the news of the murder of Commodore Goodenough at Santa Cruz. Commodore Goodenough was one of those persons to have met whom makes a man feel himself distinctly the better for his interviews and intercourse He was not only a typical representative of what is called "Armed Science," he not only possessed the eye to watch and the arm to strike, happily so common in our two services, but he added to all this a cultivation and refinement duly set forth and typified by manners which were

"not idle but the fruit
Of loyal nature and of noble mind."

It is indeed a "puzzling world," as it has been forcibly phrased, in which such a man loses his life, and we lose his power for good, through the act of what Wordsworth calls

"A savage, loathsome, vengeful, and impure."

Still Corfe Castle is near enough to Bristol to prevent us from forgetting that we ourselves were once as treacherous and murderous as the modern Papuans, and that less than 900 years ago. If we have improved, there is hope for them.

† Farrar on the Growth of Language: pp. 17, 18, Journal of Philology, 1868.

‡ Hackel, 'Anthropogenie,' 1874, p. 361.

I would venture to say that the way in which a person with the command of a considerable number of skulls procured from some one district in modern times, or from some one kind of tumulus or sepulchre in prehistoric times, would naturally address himself to the work of arranging them in a museum, furnishes us with a concrete illustration of the true limits of craniography. I say "a person with the command of a considerable number of skulls;" for, valuable as a single skull may be, and often is, as furnishing the missing link in a gradational series, one or two skulls by themselves do not justify us (except in rare instances, which I will hereinafter specify) in predicating any thing as to their nationality. Greater rashness has never been shown, even in a realm of science in which rashness has only recently been proceeded against under an Alien Act, than in certain speculations as to the immigration of races into various corners of the world, based upon the casual discovery in such places of single skulls, which skulls were identified, on the ground of their individual characters, as having belonged to races shown on no other evidence to have ever set foot there.

It is, of course, possible enough for a skilled craniographer to be right in referring even a single skull to some particular nationality; an Australian or an Eskimo, or an Andamanese might be so referred with some confidence; but all such successes should be recorded with the reservation suggested by the words, *ubi eorum qui perierunt?* and by the English line, "the many fail, the one succeeds." They are the shots which have hit, and have been recorded. But if it is unsafe to base any ethnographic conclusions upon the examination of one or two skulls, it is not so when we can examine about ten times as many—ten, that is to say, or twenty, the locality and the dates of which are known as certain quantities. A craniographer thus fortunate casts his eye over the entire series, and selects from it one or more which correspond to one of the great types based by Retzius not merely upon consideration of proportionate lengths and breadths, but also upon the artistic considerations of type, curve, and contour. He measures the skulls thus selected, and so furnishes himself with a check which even the most practised eye cannot safely dispense with. He then proceeds to satisfy himself as to whether the entire series is referable to one alone of the two great typical forms of Brachycephaly or Dolichocephaly, or whether both types are represented in it, and if so, in what proportions and with what admixture of intermediate forms. With a number of Peruvian, or, indeed, of Western American skulls generally, of Australian, of Tasmanian, of Eskimo, of Veddah, of Andamanese crania before him, the craniographer would nearly always, setting aside a few abnormally aberrant (which are frequently morbid) specimens, refer them all to one single type*.

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* It is not by any means entirely correct to say that there is no variety observable among races living in isolated savage purity. The good people of Baden who, when they first saw them, said all the Bashkirs in a regiment brought up to the Rhine in 1813 by the Russians were as like to each other as twins, found, in the course of a few weeks, that they could distinguish them readily and sharply enough (see Ecker, 'Crania Germaniæ

Matters would be very different when the craniographer came to deal with a mixed race like our own, or like the population of Switzerland, the investigation into the craniology of which has resulted in the production of the invaluable 'Crania Helvetica' of His and Rutimeyer. At once, upon the first inspection of a series of crania, or, indeed, of heads, from such a race, it is evident that some are referable to one, some to another, of one, two, or three typical forms, and that a residue remains whose existence and character is perhaps explained and expressed by calling them "Mischformen." Then arises a most interesting question—Has the result of intercrossing been such as to give a preponderance to these "Mischformen?" or has it not rather been such as in the ultimate resort, whilst still testified to by the presence of intermediating and interconnecting links, to have left the originally distinct forms still in something like their original independence, and in the possession of an unoverwhelmed numerical representation? The latter of these two alternative possibilities is certainly often to be seen realized within the limits of a modern so-called "English" or so-called "British" family; and His has laid this down as being the result of the investigations above-mentioned into the Ethnology of Switzerland. At the same time it is of cardinal importance to note that His has recorded, though only in a footnote, that the skulls which combine the characters of his two best-defined types, the "Sion-Typus" to wit, and the "Disentis-Typus," in the "Mischform" which he calls "Sion-Disentis Mischlinge," are the most capacious of the entire series of the "Crania Helvetica," exceeding, not by their maximum only, but by their average capacity also, the corresponding capacities of every one of the pure Swiss types *. Intercrossing, therefore, is an agency which in one set of cases may operate in the way of enhancing individual evolution, whilst in another it so divides its influence as to allow of the maintenance of two types in their distinctness. Both these results are of equal biological, the latter is of preeminent archæological interest. Retzius † was of opinion, and, with a few qualifications, I think, more recent Swedish Ethnologists would agree, that the modern dolichocephalic Swedish cranium was very closely affined to, if not an exact reproduction of the Swedish cranium of the Stone Period; and Virchow ‡ holds that the modern brachycephalic Danish skull is similarly related to the Danish skull of the same period. There can be no doubt that the Swedish cranium is very closely similar indeed to the Anglo-Saxon; and the skulls which still conform to that type amongst us will be by most men supposed to be the legitimate representatives of the followers of Hengest and Horsa, just as the modern Swedes, whose country has been less subjected to disturbing agencies, must be held to be the lineal descendants of the original occupiers of their soil. I am inclined to think that the permanence of the brachycephalic stock and type in Denmark has also its bearing upon the Ethnography of this country. In the Round-Barrow or Bronze Period in this country, sub-spheroidal crania (that is to say, crania of a totally different shape and type from those which are found in exclusive possession of the older and longer Barrows) are found in great abundance, sometimes, as in the South, in exclusive possession of the sepulchre, sometimes in company, as in the North, with skulls of the older type. The skulls are often strikingly like those of the same type from the Danish tumuli. On this coincidence I should not stake much, were it not confirmed by other indications. And foremost amongst these indications I should place the fact of the "Tree-interments," as they have been called (interments, that is, in coffins made out of the trunk of a tree), of this country, and of Denmark, being so closely alike. The well-known

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Occid.' p. 2; 'Archiv für Anthrop.' v. p. 485, 1872). And real naturalists, such as Mr. Bates, practised in the discrimination of zoological differences, express themselves as struck rather with the amount of unlikeness than with that of likeness which prevails amongst savage tribes of the greatest simplicity of life and the most entire freedom from crossing with other races. But these observations relate to the *living heads*, not to the skulls.

* See Dr. Beddoe, Mem. Soc. Anth. Lond. iii. p. 552; Huth, p. 308, 1875; D. Wilson, cit. Brace, 'Races of the Old World,' p. 380; and His, 'Crania Helvetica.'

† Ethnologische Schriften, p. 7.

‡ Archiv für Anthropologie, iv. pp. 71 and 80.

monoxylic coffin from Gristhorpe contained, together with other relics closely similar to the relics found at Treenhoi, in South Jutland, in a similar coffin, a skull which, as I can testify from a cast given me by my friend Mr. H. S. Harland, might very well pass for that of a brachycephalic Dane of the Neolithic period. Canon Greenwell discovered a similar monoxylic coffin at Skipton, in Yorkshire; and two others have been recorded from the same county—one from the neighbourhood of Driffield, the other from that of Thornborough. Evidence, again, is drawn from Col. Lane Fox's opinion that the earthworks which form such striking objects for inquiry here and there on the East-Riding Wolds must, considering that the art of war has been the same in its broad features in all ages, have been thrown up by an invading force advancing from the east coast. Now we do know that England was not only made England by immigration from that corner or angle where the Cimbric Peninsula joins the main land, but that long after that change of her name this country was successfully invaded from that Peninsula itself. And what Swegen and Cnut did some four hundred and fifty years after the time of Hengist and Horsa, it is not unreasonable to suppose other warriors and other tribes from the same locality may have done perhaps twice or thrice as many centuries further back in time than the Saxon Conquest. The huge proportions of the Cimbri, Teutones, and Ambrones are just what the skeletons of the British Round-Barrow folk enable us now to reproduce for ourselves. It is much to be regretted that from the vast slaughters of Aquæ Sextiæ and Vercellæ, no relics have been preserved which might have enabled us to say whether Boiorix and his companions had the cephalic proportions of Neolithic Danes, or those very different contours which we are familiar with from Saxon graves throughout England, and from the so-called "Danes' graves" of Yorkshire. Whatever might be the result of such a discovery and such a comparison, I think it would in neither event justify the application of the term "Kymric" to the particular form of skull to which Retzius and Broca have assigned it.

Some years ago I noticed the absence of the brachycephalic British type of skull from an extensive series of Romano-British skulls which had come into my hands; and subsequently to my doing this, Canon Greenwell pointed out to me that such skulls as we had from late Keltic cemeteries, belonging to the comparatively short period which elapsed between the end of the Bronze Period and the establishment of Roman rule in Great Britain, seemed to have reverted mostly to the præ-Bronze dolichocephalic type. This latter type, the "kumbecephalic type" of Professor Daniel Wilson, manifests a singular vitality, as the late and much lamented Professor Phillips pointed out long ago at a Meeting of this Association held at Swansea—the dark-haired variety, which is very ordinarily the longer-headed and the shorter-statured variety of our countrymen, being represented in very great abundance in those regions of England which can be shown, by irrefragable and multifold evidence, to have been most thoroughly permeated, imbibed, and metamorphosed by the infusion of Saxons and Danes, in the districts, to wit, of Derby, Leicester, Stamford, and Loughborough. How, and in what way, this type of man, one to which some of the most valuable men now bearing the name of Englishman, which they once abhorred, belong, has contrived to reassert itself, we may, if I am rightly informed, hear some discussion in this department. Before leaving this part of my subject I would say that the Danish type of head still survives amongst us; but it is to my thinking not by any means so common, at least in the Midland counties, as the dark-haired type of which we have just been speaking. And I would add that I hope I may find that the views which I have here hinted at will be found to be in accord with the extensive researches of Dr. Beddoe, a gentleman who worthily represents and upholds the interests of Anthropology in this city, the city of Prichard, and who is considered to be more or less disqualified for occupying the post which I now hold, mainly from the fact that he has occupied it before, and that the rules of the British Association, like the laws of England, have more or less of an abhorrence of perpetuities.

The largest result which craniometry and cubage of skulls have attained is, to my thinking, the demonstration of the following facts, viz.:—first, that the cubical contents of many skulls from the earliest sepultures from which we have any skulls at all, are larger considerably than the average cubical contents of modern European skulls; and secondly, that the female skulls of those times did not contrast to that disadvantage with the skulls of their male contemporaries which the average female skulls of modern days do, when subjected to a similar comparison *. Dr. Thurnam demonstrated the former of these facts, as regards the skulls from the Long and the Round Barrows of Wiltshire, in the Memoirs of the London Anthropological Society for 1865; and the names of Les Eyzies and Cro-Magnon, and of the Caverne de l'Homme Mort, to which we may add that of Solutré, remind us that the first of these facts has been confirmed, and the second both indicated and abundantly commented upon by M. Broca.

The impression which these facts make upon one, when one first comes to realize them, is closely similar to that which is made by the first realization to the mind of the existence of a subtropical Flora in Greenland in Miocene times. All our anticipations are precisely reversed, and in each case by a weight of demonstration equivalent to such a work; there is no possibility in either case of any mistake; and we acknowledge that all that we had expected is absent, and that where we had looked for poverty and pinching there we come upon luxurious and exuberant growth. The comparisons we draw in either case between the past and the present are not wholly to the advantage of the latter: still such are the facts. Philologists will thank me for reminding them of Mr. Chauncy Wright's brilliant suggestions that the large relative size of brain to body which distinguishes, and always, so far as we know, has distinguished the human species as compared with the species most nearly related to it, may be explained by the psychological tenet that the smallest proficiency in the faculty of language may "require more brain power than the greatest in any other direction," and that "we do not know and have no means of knowing what is the quantity of intellectual power as measured by brains which even the simplest use of language requires" †.

And for the explanation of the preeminently large size of the brains of these particular representatives of our species, the tenants of prehistoric sepulchres, we have to bear in mind, first, that they were, as the smallness of their numbers and the largeness of the tumuli lodging them may be taken to prove, the chiefs of their tribes; and, secondly, that modern savages have been known, and prehistoric savages may therefore be supposed, to have occasionally elected their chiefs to their chieftainships upon grounds furnished by their superior fitness for such posts—that is to say, for their superior energy and ability. Some persons may find it difficult to believe this, though such facts are deposed to by most thoroughly trustworthy travellers, such as Baron Osten Sacken (referred to by Von Baer, in the Report of the famous Anthropological Congress at Gottingen in 1861, p. 22). And they may object to accepting it, for, among other reasons, this reason—to wit, that Mr. Galton has shown us in his 'Men of Science, their Nature and Nurture,' p. 98, that men of great energy and activity (that is to say, just the very men fitted to act as leaders of and to commend themselves to savages)‡ have ordinarly smaller-sized heads than men possessed of intellectual power dissociated from those qualities.

The objection I specify, as well as those which I allude to, may have too much weight assigned to them; but we can waive this discussion and put our feet on firm ground when we say that in all savage communities the chiefs have a larger share of food and other comforts, such as there are in savage life, and have consequently better and larger frames—or, as the Rev. S. Whitmee puts it (*l. c.*), when observing on the fact as noticed by him in Polynesia, a more "portly bearing." This (which, as the size of the brain increases within certain proportions with the increase of the size of the body, is a material fact in every sense) has been testified to by a multitude of other observers, and is, to my mind, one of the most distinctive marks of savagery as opposed to civilization. It is only in times of civilization that men of the puny stature of Tydeus or Agesilaus are allowed their proper place in the management of affairs. And men of such physical size, coupled with such mental calibre, may take comfort, if they need it, from the purely quantitative consideration, that large as are the individual skulls from prehistoric graves, and high, too, as is the average obtained from a number of them, it has nevertheless not been shown that the largest individual skulls of those days were larger than, or, indeed, as large as the best skulls of our own days; whilst the high average capacity which the former series shows is readily explicable by the very obvious consideration that the poorer specimens of humanity, if allowed to live at all in those days, were, at any rate, when dead not allowed sepulture in the "tombs of the kings," from which nearly exclusively we obtain our prehistoric crania. M. Broca* has given us yet further ground for retaining our self-complacency by showing, from his extensive series of measurements of the crania from successive epochs in Parisian burial-places, that the average capacity has gone on steadily increasing.

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* The subequality of the male and female skulls in the less civilized of modern races was pointed out as long ago as 1845, by Retzius in Müller's 'Archiv,' p. 89, and was commented upon by Huschke, of Jena, in his 'Schädel, Hirn und Seele,' pp. 48–51, in 1854.

† The bibliographer will thank me also for pointing out to him that the important paper in the 'North-American Review,' for October, for 1870, p. 295, from which I have just quoted, has actually escaped the wonderfully exhaustive research of Dr. Seidlitz (see his 'Darwin'sche Theorie,' 1875).

‡ An interesting and instructive story in illustration of the kind of qualities which do recommend a man to savages, is told us by Sir Bartle Frere in his pamphlet, 'Christianity suited to all forms of Civilization,' pp. 12–14.

It may be suggested that a large brain, as calculated by the cubage of the skull, may nevertheless have been a comparatively lowly organized one, from having its molecular constitution qualitatively inferior from the neuroglia being developed to the disadvantage of the neurine, or from having its convolutions few and simple, and being thus poorer in the aggregate mass of its grey vesicular matter. It is perhaps, impossible to dispose absolutely of either of these suggestions. But, as regards the first, it seems to me to be exceedingly improbable that such could have been the case. For in cases where an overgrowth of neuroglia has given the brain increase of bulk without giving it increase of its true nervous elements, the Scotch proverb, "Muckle brain, little wit" applies; and the relatively inferior intelligence of the owners of such brains as seen nowadays may, on the principle of continuity, be supposed to have attached to the owners of such brains in former times. But those times were times of a severer struggle for existence than even the present; and inferior intelligences, and specially the inferior quickness and readiness observable in such cases, it may well be supposed, would have fared worse then than now. There is, however, no need for this supposition; for, as a matter of fact, the braincase of brains so hypertrophied† has a very readily recognizable shape of its own, and this shape is not the shape of the Cro-Magnon skull, nor indeed of any of the Prehistoric skulls with which I am acquainted.

As regards the second suggestion, to the effect that a large braincase may have contained a brain the convolutions of which were simple, broad, and coarse, and which made up by consequence a sheet of grey matter of less square area than that made up in a brain of similar size but of more complex and slenderer convolutions, I have to say that it is possible this may have been the case, but that it seems to me by no means likely. Very large skulls are sometimes found amongst collections purporting to have come from very savage or degraded races; such a skull may be seen in the London College of Surgeons with a label, "5357 D. Bushman, G. Williams. Presented by Sir John Lubbock;" and, from what Professor Marshall and Gratiolet have taught us as to other Bushman brains, smaller, it is true, in size, we may be inclined to think that the brain which this large skull once contained may nevertheless have been much simpler in its convolutions than a European brain of similar size would be. This skull, however, is an isolated instance of such proportions amongst Bushman skulls, so far, at least, as I have been able to discover; whilst the skulls of Prehistoric times, though not invariably, are yet most ordinarily large skulls. A large brain with coarse convolutions puts its possessor at a disadvantage in the struggle for existence, as its greater size is not compensated by greater dynamical activity; and hence I should be slow to explain the large size of ancient skulls by suggesting that they contained brains of this negative character. And I am glad to see that M. Broca is emphatically of this opinion, and that, after a judicious statement of the whole case, he expresses himself thus (Revue d'Anthropologie, ii. 1, 38):—"Rien ne permet donc de supposer que les rapports de la masse encéphalique avec l'intelligence fussent autres chez eux que chez nous."

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* See his paper, 'Bull. Soc. Anthrop. de Paris,' t. iii. ser. i. 1862, p. 102; or his collected Mémoires, vol. i. p. 348, 1871.

† I may, perhaps, be allowed to express here my surprise at the statement made by Messrs. Wilks and Moxon, in their very valuable Pathological Anatomy, pp. 217, 218, to the effect that they have not met with such cases of Cerebral Hypertrophy. They were common enough at the Children's Hospital in Great Ormond Street when I was attached to it.

It is by a reference to the greater severity of the struggle for existence and to the lesser degree to which the principle of division of labour was carried out in olden days that M. Broca, in his paper on the Caverne de l'Homme Mort just quoted from, explains the fact of the subequality of the skulls in the two sexes. This is an adequate explanation of the facts; but to the facts as already stated, I can add from my own experience the fact that though the female skulls of Prehistoric times are often, they are not always equal, or nearly, to those of the male sex of those times; and, secondly, that whatever the relative size of the head, the limbs and trunk of the female portion of those tribes were, as is still the case with modern savages, very usually disproportionately smaller than those of the male. This is readily enough explicable by a reference to the operations of causes exemplifications of the working of which are unhappily not far to seek now, and may be found in any detail you please in those anthropologically interesting (however otherwise unpleasant) documents, the Police Reports.

Having before my mind the liability we are all under fallaciously to content ourselves with recording the shots which hit, I must not omit to say that one at least of the more recently propounded doctrines in Craniology does not seem to me to be firmly established. This is the doctrine of "occipital dolichocephaly" being a characteristic of the lower races of modern days and of Prehistoric races as compared with modern civilized races. I have not been able to convince myself by my own measurements of the tenability of this position; and I observe that Ihering has expressed himself to the same effect, appending his measurements in proof of his statements in his paper, "Zur Reform der Craniometrie," published in the 'Zeitschrift für Ethnologie' for 1873. The careful and extensive measurements of Aeby * and Weisbach † have shown that the occipital region enjoys wider limits of oscillation than either of the other divisions of the cranial vault. I have some regret in saying this, partly because writers on such subjects as "Literature and Dogma" have already made use of the phrase, "occipitally dolichocephalic," as if it represented one of the permanent acquisitions of science; and I say it with even more regret, as it concerns the deservedly honoured names of Gratiolet and of Broca, to whom Anthropology owes so much. What is true in the doctrine relates, among other things, to what is matter of common observation as to the fore part of the head rather than to any thing which is really constant in the back part of the skull. This matter of common observation is to the effect that when the ear is "well forward" in the head, we do ill to augur well of the intelligence of its owner. Now the fore part of the brain is irrigated by the carotid arteries, which, though smaller in calibre during the first years of life, during which the brain so nearly attains its full size, than they are in the adult, are nevertheless relatively large even in those early days, and are both absolutely, and relatively to the brain which they have to nourish, much larger than the vertebral arteries, which feed its posterior lobes. It is easy therefore to see that a brain in which the fore part supplied by the carotids has been stinted of due supplies of food, or however stunted in growth, is a brain the entire length and breadth of which is likely to be ill-nourished. As I have never seen reason to believe in any cerebral localization which was not explicable by a reference to vascular irrigation, it was with much pleasure that I read the remarks of Messrs. Wilks and Moxon in their recently published 'Pathological Anatomy,' pp. 207, 208, as to the indications furnished by the distribution of the Pacchionian bodies as to differences existing in the blood-currents on the back and those on the fore part of the brain. These remarks are the more valuable, as mere hydraulics, Professor Clifton assures me, would not have so clearly pointed out what the physiological upgrowths seem to indicate. Any increase, again, in the length of the posterior cerebral arteries is *pro tanto* a disadvantage to the parts they feed. If the blood-current, as these

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* Aeby, 'Schädelform des Menschen und der Affen,' pp. 11, 12, and 128.

† Weisbach, 'Die Schädelform der Roumanen,' p. 32, 1869.

facts seem to show, is slower in the posterior lobes of the brain, it is, upon purely physical principles of endosmosis and exosmosis, plain that these segments of the brain are less efficient organs for the mind to work with; and here again "occipital dolichocephaly" would have a justification, though one founded on the facts of the nutrition of the brain-cells, not on the proportions of the braincase. In many (but not in all) parts of Continental Europe, again, the epithet "longheaded" would not have the laudatory connotation which, thanks to our Saxon blood, and in spite of the existence amongst us of other varieties of dolichocephaly, it still retains here. And the brachycephalic head which, abroad* at least, is ordinarily a more capacious one, and carried on more vigorous shoulders and by more vigorous owners altogether, than the dolichocephalic, strikes a man who has been used to live amongst dolichocephali by nothing more forcibly, when he first comes to take notice of it, than by the nearness of its external ear to the back of the head; and this may be said to constitute an artistic occipital brachycephalism. But this does not imply that the converse condition is to be found conversely correlated, nor does it justify the use of the phrase "occipital dolichocephaly" in any etymological, nor even in any ethnographical sense.

I shall now content myself, as far as craniology is concerned, by an enumeration of some at least of the various recent memoirs upon the subject which appear to me to be of preeminent value. And foremost amongst these I will mention Professor Cleland's long and elaborate scientific and artistic paper on the Variations of the Human Skull, which appeared in the Philosophical Transactions for 1869. Next I will name Ecker's admirable, though shorter, memoir on Cranial Curvature, which appeared in the 'Archiv fur Anthropologie,' a journal already owing much to his labours, in the year 1871. Aeby's writings I have already referred to, and Ihering's, to be found in recent numbers of the 'Archiv fur Anthropologie' and the 'Zeitschrift fur Ethnologie,' deserve your notice. Professor Bischoff's paper on the Mutual Relations of the horizontal circumference of the Skull and of its contents to each other and to the weight of the Brain, has not, as I think, obtained the notice which it deserves. It is to be found in the Proceedings of the Royal Society of Munich for 1864, the same year which witnessed the publication of the now constantly quoted 'Crania Helvetica,' of Professors His and Rutimeyer. Some of the most important results contained in this work, and much important matter besides, was made available to the exclusively English reader by Professor Huxley, two years later, in the 'Prehistoric Remains of Caithness.' I have made a list, perhaps not an exhaustive one, but containing some dozen memoirs by Dr. Beddoe, and having read them or nearly all of them, I can with a very safe conscience recommend you all to do the like. I can say nearly the same as regards Broca and Virchow, adding that the former of these two savans has set the other two with whom I have coupled him an excellent example, by collecting and publishing his papers in consecutive volumes.

But I should forget not only what is due to the place in which I am speaking, but what is due to the subject I am here concerned with, if in speaking of its literature, I omitted the name of your own townsman, Prichard. He has been called, and, I think, justly, the "father of modern Anthropology." I am but putting the same thing in other words, and adding something more specific to it, when I compare his works to those of Gibbon and Thirlwall, and say that they have attained and seem likely to maintain permanently a position and importance commensurate with that of the "stately and undecaying" productions of those great English Historians. Subsequently to the first appearance of those histories other works have appeared by other authors, who have dealt in them with the same periods of time. I have no wish to depreciate those works; their authors have not rarely rectified a slip and corrected an error into which their great predecessors had fallen. Nay, more, the later comers have by no means neglected to avail themselves of the advantages which the increase of knowledge and the vast political experience of the last thirty years have put at their disposal, and they have thus occasionally had opportunities of showing more of the true proportions and relations of even great events and catastrophes; still the older works retain a lasting value, and will remain as solid testimonies to English intellect and English capacity for large undertakings as long as our now rapidly extending language and literature live. The same may be most truthfully said of Prichard's 'Researches into the Physical History of Mankind.' An increase of knowledge may supply us with fresh and with stronger arguments than he could command for some of the great conclusions for which he contended; such, notably, has been the case in the question (though "question" it can no longer be called) of the Unity of the human species; and by the employment of the philosophy of continuity and the doctrine of evolution, with which the world was not made acquainted till more than ten years after Prichard's death, many a weaker man than he has been enabled to bind into more readily manageable burdens the vast collections of facts with which he had to deal. Still his works remain, massive, impressive, enduring—much as the headlands along our southern coast stand out in the distance in their own grand outlines, whilst a close and minute inspection is necessary for the discernment of the forts and fosses added to them, indeed dug out of their substance in recent times. If we consider what the condition of the subject was when Prichard addressed himself to it, we shall be the better qualified to take and make an estimate of his merits. This Prichard has himself described to us, in a passage to be found in the preface to the third volume of the third edition of the 'Physical History,' published in the year 1841, and reminding one forcibly of a similar utterance of Aristotle's, at the end of one of his logical treatises (Soph. Elench. cap. xxxiv. 6). These are his words:—

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* See upon this point:—Broca, Bull. Soc. Anth. Paris, ii. p. 648, 1861; *ibid.* Dec. 5, 1872; Virchow, Archiv für Anth. v. p. 535; Zeitschrift für Ethnol. iv. 2, p. 36; Sammlungen, ix. 193, p. 45, 1874; Beddoe, Mem. Anth. Soc. Lond. ii. p. 350.

"No other writer has surveyed the same field, or any great part of it, from a similar point of view. . . . The lucubrations of Herder and other diffuse writers of the same description, while some of them possess a merit of their own, are not concerned in the same design, or directed towards the same scope. Their object is to portray national character as resulting from combined influences—physical, moral, and political. They abound in generalizations, often in the speculative flights of a discursive fancy, and afford little or no aid for the close induction from facts, which is the aim of the present work. Nor have these inquiries often come within the view of writers on Geography, though the history of the globe is very incomplete without that of its human inhabitants." A generation has scarcely passed away since these words were published in 1841; we are living in 1875; yet what a change has been effected in the condition of Anthropological literature! The existence of such a dignified quarterly as the 'Archiv fur Anthropologie,' bearing on its titlepage in alphabetical order the honoured names of V. Baer, of Desor, of Ecker, of Hellwald, of His, of Lindenschmidt, of Lucæ, of Rutimeyer, of Schaafhausen, of Semper, of Virchow, of Vogt, and of Welcker, is in itself perhaps the most striking evidence of the advance made in this time, as being the most distinctly ponderable and in every sense the largest Anthropological publication of the day.

Archæology, which but a short time back was studied in a way which admirably qualified its devotees for being called "connoisseurs," but which scarcely qualified them for being called men of Science, has by its alliance with Natural History and its adoption of Natural-History methods, and its availing itself of the light afforded by the great Natural-History principles just alluded to, entered on a new career. There is, as regards Natural History, Anatomy, and Pathology, nothing left to be desired for the conjoint scheme represented by the periodical just mentioned, where we have V. Baer for the first and Virchow for the last, and the other names specified for the rest of these subjects; whilst Archæology, the other party in the alliance, is very adequately represented by Lindenschmidt alone. But when I recollect that Prichard published a work 'On the Eastern Origin of the Celtic Nations' ten years before the volume of 'Researches,' from which I have just quoted, and that this work has been spoken of as the work "which has made the greatest advance in Comparative Philology during the present century," I cannot but feel that the Redaction of the 'Archiv für Anthropologie' have not as yet learnt all that may be learnt from the Bristol Ethnologist; and they would do well to add to the very strong staff represented on their titlepage the name of some one, or the names of more than one comparative philologist. This the Berlin 'Zeitschrift' has done.

Of the possible curative application of some of the leading principles of modern

Anthropology to some of the prevalent errors of the day, I should be glad to be allowed to say a few words. The most important lesson as regards the future (I do not say the *immediate* future) which the modern study of Human Progress (for such all men who think, except the Duke of Argyll, are now agreed is the study of Anthropology) teaches is the folly and impossibility of attempting to break abruptly with the past. This principle is now enforced with persistent iteration from many Anthropological platforms; and I cannot but think it might advantageously be substituted in certain portfolios for the older maxim, "Whatever is certainly new is certainly false," a maxim which seems at first sight somewhat like it, but which, as being based on pure ignorance of the past and teaching only distrust of the future, is really quite different from it. I am not sure that Prichard ever put forward the former of these two doctrines, though it is just the doctrine which would have commended itself to his large philosophical, many-sided, well-balanced judgment. He died in 1848—the very year which perhaps, of all save one in history, and that one the year 1793 (a year in which he was yet a child), showed in the most palpable way the absurdity of attempting to make civilization by pattern, and of hoping to produce a wholesome future in any other way than that of evolution from the past.

What have been called the senile, what could equally well have been called the cynical Ethics of Pessimism, had not in Prichard's time found any advocates in this country; indeed, so far as I have observed, they are of a more recent importation than most other modern heresies. I do not deny that at times it is possible to give way to certain pressing temptations to think that we are living in a certainly deteriorated and a surely deteriorating age, and that it is hopeless and useless to set up, or look up to, aspirations or ideals. When, for example, we take stock of the avidity with which we have, all of us, within the last twelve months read the memoirs of a man whom one of his reviewers has called a "high-toned aristocrat," but whom I should call by quite another set of epithets, we may think that we are not, after all, so much the better for the 3000 years which separate us from the time when it was considered foul play for a man to enact the part of a familiar friend, to eat of another man's bread, and then to lay great wait for him. Or can we, in these days, bear the contrast to this miserable spectacle of mean treachery and paltry disloyalty, which is forced upon us in the same history by the conduct of the chivalrous son of Zeruiah, who, when he had fought against Rabbah and taken the city of waters, sent for his king who had tarried in Jerusalem, lest that city should thenceforward bear the name, not of David, but of Joab? Or again, as I have been asked, have we got very far above the level of sentiment and sympathy which Helen, an unimpeachable witness, tells us the Trojan Hector had attained to and manifested in his treatment of her,

"With tender feeling and with gentle words"?

Would the utterances of any modern epic poet have so surely brought tears into the eyes of the noble-hearted boy depicted by Mr. Hughes, as the passage of Homer just alluded to, and characterized by him "as the most touching thing in Homer, perhaps in all profane poetry put together"? What answer can be made to all this by those who maintain that the old times were not better than these, who maintain the doctrine of Progress, and hold that man has been gradually improving from the earliest times, and may be expected to go on thus advancing in the future? An answer based upon the employment of simple scientific method, and upon the observance of a very simple scientific rule—upon, to wit, the simple method of taking averages, and the simple rule of enumerating all the circumstances of the case. Noble actions, when we come to count them up, were not, after all, so very common in the olden times; and side by side with them there existed, and indeed flourished, intertwined with them, practices which the moral sense of all civilized nations has now definitely repudiated. It is a disagreeable task, that of learning the whole truth; but it is unfair to draw dark conclusions as to the future, based on evidence drawn from an exclusive contemplation of the bright side of the past. A French work, published only last year, was recommended to me recently by an eminent scholar as containing a good account of the intellectual and moral condition of the Romans under the Empire. I have the book, but have not been able to find in it any mention of the gladiatorial shows, though one might have thought the words *Panem et Circenses* might have suggested that those exhibitions entered as factors of some importance into the formation of the Roman character. It is impossible to go beyond that in the way of looking only at the bright side of things. Still we ourselves have less difficulty in recollecting that there were 300 Spartans sacrificed to the law-abiding instincts of their race at Thermopylæ, than in producing, when asked for them, the numbers of Helots whom Spartan policy massacred in cold blood not so many years after, or those of the Melians and Mitylenæans whom the polished and cultivated Athenians butchered in the same way, and about the same time, with as little or far less justification for doing so. Homer, whom I have above quoted, lived, it is true, some centuries earlier, but living even then he might have spared more than the five words contained in a single line (176 of 'Iliad' xxiii.) to express reprobation for the slaughter of the twelve Trojan youths at the pyre of Patroclus. The Romans could applaud Terence's line, "Homo sum, humani nihil a me alienum puto;" but it did not strike them till the time of Seneca that these noble words were incompatible with the existence of gladiatorial shows, nor till the time of Honorius did they legally abolish those abominations. Mutinies and rebellions are not altogether free from unpleasant incidents even in our days; but the execution of 6000 captives from a Servile war, in the way that Crassus executed his prisoners after the final defeat of Spartacus, viz. by the slow torture of crucifixion, is, owing to the advance of civilization, no longer a possibility. If the road from Capua to Rome witnessed this colossal atrocity, there are still preserved for us in its near neighbourhood the remains of Herculaneum and Pompeii to show us what foul broad-daylight exuberance could be allowed by the public conscience of the time of Titus and Agricola to that other form which sits "hard by Hate." The man who in those days contributed his factor to the formation of a better public opinion, did so at much greater risk than any of us can incur now by the like line of action. Much of what was most cruel, much of what was most foul in the daily life of the time, had, M. Gaston Boissier notwithstanding, the sanction of their state religion and the indorsement of their Statesmen and Emperors to support it. There was no public press in other lands to appeal to from the falsified verdicts of a sophisticated or a terrorized community. Though then as now,

"Mankind were one in spirit,"

freedom of intercommunication was non-existent; no one could have added to the words just quoted from Lowell their complemental words,

" And an instinct bears along,
" Round the earth's electric circle the swift flash of right or wrong."

The solidarity of nations had not, perhaps could not have been dreamt of—the physical prerequisites for that, as for many another non-physical good, being wanting.

Under all these disadvantages men were still found who were capable of aspiration, of hope for, and of love of better things; and by constant striving after their own ideal, they helped in securing for us the very really improved material, mental, and moral positions which we enjoy. What they did before, we have to do for those who will come after us.

BOTANY.

[For Dr. Sclater's Address see page 85.]

Notice of Rare Plants from Scotland. By Prof. BALFOUR, *F.R.S., F.R.S.E.*

Notes on Turneraceæ *from Rodriguez. By* I. BAYLEY BALFOUR, *D.Sc.*

General Remarks on the Geological Structure and Flora of the Mascarene Islands. By I. Bayley Balfour, *D.Sc.*

The geological structure of the principal islands of the Mascarene group, viz. Bourbon, Mauritius, and Rodriguez, was briefly described. These islands are all of volcanic origin, the rock being chiefly a very dark compact basalt. Each island, however, has not been altogether formed at one period. This fact is particularly well illustrated in Bourbon, where the N.W. portion is of more ancient date than the S.E., in which latter part there exists at present an active volcano. Consequent on this difference of age the rocks are of a different character; and this has a corresponding effect upon the vegetation of the two districts. These differences are such as characterize the flora of a dry as opposed to a moist region.

The type of the Mascarene flora was shown to be Indian, although the islands are nearer to the African continent than to India; and the comparative absence of endemic types was indicated.

After detailing several facts regarding resemblances betwixt the floras of the islands, and a brief reference to their fauna existing and extinct, the author indicated the bearings of the geological structure and of the flora upon the question of the separate origin of the islands, or of their being merely fragments of a preexisting continent which also embraced Madagascar and the Seychelles.

On an Abnormality of Primula vulgaris *with Interpetaline Lobes.*
By Prof. A. Dickson, *M.D.*

The abnormal flowers exhibited were collected in 1874 at Pitlochrie, Perthshire, by the late Professor Inglis, of Aberdeen. The peculiarity consists in the development of five narrow petaloid segments, which alternate with the lobes of the corolla. These are not organs simply adherent to the inner surface of the corolla-tube like "epipetalous" stamens, but their bases form a continuous sheet of tissue with the petals. At first sight the abnormality appears to resemble the "doubling" of the primrose often seen in cultivation. In the ordinary double primrose, however, the additional petaloid lobes are metamorphosed stamens, and are opposite to (not alternate with) the lobes of the corolla. In the abnormality exhibited the superadded petaloid pieces are simply interpetaline lobes analogous to the intersepaline lobes of *Nemophila*, *Campanula medium*, &c. One of the most interesting points connected with this is that in the order Primulaceæ we have a genus, *Soldanella*, in which interpetaline lobes occur. In *S. montana*, for example, the limb of the corolla exhibits five broader lobes, which are trifid, and five narrower ones, which are entire. The five trifid lobes represent the petals proper, while the five entire ones are interpetaline lobes. In the monstrous *Primula* we have thus an abnormality imitating, so to speak, the normal condition of an allied genus.

On a Monstrosity in Saxifraga stellaris. *By* Prof. A. Dickson, *M.D.*

The plant from which the specimens exhibited were obtained was found by Dr. A. P. Aitken, of Edinburgh, in July last, on Ben Challum near Tyndrum. It had three flowering stems, which about their middle exhibited a few scattered narrow bracts with what appear to be viviparous buds in their axils. Each of these stems is terminated by a monstrous flower, with somewhat numerous sepals in several series. Petals absent; stamens about as many as the sepals; and a vast number of separate carpels, forming an apocarpous gynæcium almost like that in *Ranunculus*. This monstrosity is almost exactly parallel to the monstrous flowers not unfrequently found terminating the inflorescence of *Digitalis purpurea*, where we have a multiplication of the parts of the floral envelopes and andrœcium, and a pistil composed often of several whorls of carpels.

On Abnormal Flowers of Tropæolum. *By* Prof. A. Dickson, *M.D.*

On a Variety of Polypodium vulgare. *By* Prof. W. R. McNab, *M.D.*

Dr. M‘Nab exhibited and described an abnormal frond of the common polypody (*Polypodium vulgare*) which had been given him by Captain Jones, of Pembroke Road, Clifton, Bristol, and in whose magnificent collection the plant producing it was grown. The plant had been gathered in a wild state by Captain Jones, and has been cultivated by him for some time. The leaf was about nine inches long, and may be briefly described as a combination of the variety *cambricum* and the typical form. The basal pinna was bipinnatifid, the segments of the first order being so deeply cut as to be pinnatipartite. The first lower pinnule (left) of the basal pinna was divided like the main portion of the pinna. The second pinna (right) was similarly divided, but larger than the first, the first lower pinnule being very much divided. The third pinna (left) was pinnatipartite, with pinnatifid divisions; and this pinna, unlike the first and second, had the basal pinnule very small. The fourth pinna (right) is below almost undivided, like normal *P. vulgare*, but with the upper two thirds divided. The next pinna is on the right side and is normal; there is a space on the opposite side caused by the displacement of the fifth pinna (left), which is exceedingly small and undivided. The seventh pinna (right) is normal. The seventh and ninth pinnæ are close together and much divided, the eighth (right), which is normal, being succeeded by a series of normal pinnæ. The upper part of the leaf is covered with sporangia, while the lower abnormal portion is not fertile. Another leaf was shown which was entirely bipinnatifid.

In these leaves the normal basifugal and apical mode of growth was observable. The pinnæ at the base assumed somewhat the form of the upper part; and it was evident that long-continued growth, apical and basifugal, had taken place in the lower pinnules, the greater portion of which were tender and delicate, and showed a marked contrast in texture to the upper fertile part of the leaf.

Hofmeister has shown that the branching of fern-leaves is dichotomous, the right and left fork-branches being alternately developed as a pinnule, and a sympodium or false axis produced by the other branches. In *Polypodium vulgare* a single central pseudaxis is produced, while in the abnormal form just described the lower pinnæ become sympodially developed; and in two cases the first pinnule of each has a well-marked sympodial development.

On a Variety of Rubus. *By* Prof. W. R. M‘Nab, *M.D.*

This *Rubus* was discovered by Captain Jones, of Clifton, in the neighbourhood of Bristol. It is a variety with very narrow leaves, not unlike the fern-leaved beech. The leaves are trifoliate, the terminal leaflet being the largest, the two lateral ones very small and poorly developed.

On the Application of the Fibre of Adansonia digitata. *By* J. J. Monteiro.

On Spiranthes Romanzoviana. *By* David Moore, *Ph.D.*

On a rare Species of Fungus found in Surrey. By Cecil H. Sp. Perceval.

The specimen which was exhibited was one of the Gasteromycetous family, and of the order Trichogastres, its specific name being *Batarrea phalloides*, P.

This fungus was one of four found growing on the ground in the interior of an old hollow pollard-ash, in the grounds of the Earl of Egmont at Nork, near Epsom, in Surrey, from which place *Clavaria ardenia* (Sow., pl. 215) also dates its name. It was found by the exhibitor on December 12, 1872, and had not, he was told, been met with for several years. The soil in the tree was *very* light and dusty, composed chiefly of the decayed *débris* of the old tree mixed with sandy mould scratched up by rabbits. The largest specimen was 12 inches in height, and its pileiform volva 2¼ inches across the top; the whole was covered with brown dust-like spores. The pileiform volva was on the exterior covered with raised reticulations with pieces of the *exterior volva* adhering to it; and on the inner side next the stem it was smooth and of a paler colour, somewhat whitish.

The stem was rough and fibrous, of a woody nature, and slightly attenuated upwards; it was buried 3 or 4 inches in the soil. At its base were the remains of the lower part of the volva. All the plants were quite dry and covered very thickly with the brown spores.

The largest specimen is in the possession of Mr. Worthington G. Smith, who, appreciating the rarity of the plant, has had it mounted under a glass, in the same manner as a picture. The next best is deposited in the Museum at Kew, where it receives the full benefit of the sun, which has, as might be expected, taken nearly all the colour out of it. The Rev. M. J. Berkeley has the third specimen, and the one exhibited has since been given to Mr. C. E. Broome for his herbarium. This latter specimen was growing on the outside of the tree, out of which, through a hole in the base, some of the soil had been scratched. It had not grown as well as the others, which were straight, well-grown specimens, but was much twisted and deformed. Every year since the finder has examined the spot, with the hope of meeting with more specimens, but with as yet no result; and last year the old tree was cut down, being dead, so that the chance of obtaining more is considerably lessened.

He has tried, as yet with no success, to raise the fungus artificially, by planting some of the spores in a pot covered with a bell-glass and kept dark in a warm moist atmosphere, the soil consisting of a mixture of *débris* from an old ash mixed with silver sand. An account of one of the specimens found, with figures, microscopical structure, &c., was written by Mr. Worthington G. Smith in the 'Gardeners' Chronicle' of August 16, 1873; and a very good coloured drawing of it is to be seen amongst Mr. W. G. Smith's collection of fungi drawings in the British Museum; also in Sowerby's 'English Fungi,' t. 390, there is a drawing of the specimen.

The following is the description in Smith's English Flora:—"Whole plant more or less of a brown hue. Exterior volva ovate, fleshy, dirty white, inclining to brown; buried 6–8 inches in the sand, with a few dirty-white floccose hairs at the base; middle volva much thinner and almost membranaceous, connected with the outer by mucilage, smooth within; inner volva internally villous, covered with very abundant yellow-brown dust-like seed; externally concave and smooth. Stem formed within the cavity of the interior volva, cylindric, straight, short, fleshy, filled with mucilage, but afterwards elongated upwards with wonderful force and quickness, and protruded through the soil, carrying with it almost the whole inner volva, adnate with its apex, and covered with a portion of the outer coat torn off in the same manner. Immediately after maturity it becomes dry, as also the volva; tubular within, and externally fibrous, and remains a long time bleached and tossed about by wind and rain."

The following is a list of the authors by whom the plant is mentioned:—

Batarrea phalloides, P.—Fr. S. M. iii. p. 7; Woodw. Phil. Trans. vol. lxxiv. p. 423, p. 26; Ann. N. H. no. 303; Smith, Spic. i. t. 12; Sow. t. 390; Pers. Syn. t. 3. f. 1; Nees, f. 257; Eng. Flor. v. p. 298; Hook. Journ. 1843, t. 22. f. 1; Bisch. f. 3463; Corda, Anl. t. E. f. 50, no. 4–6; Cooke, Br. Fungi, p. 367, f. 111; Smith, W. G., in 'Gardeners' Chronicle,' Aug. 16, 1873.

On some Fossil Seeds from the Lower Carboniferous Beds of Lancashire.

By Prof. W. C. Williamson, *F.R.S.*

M. Adolphe Brongniart has recently described a number of fossil seeds obtained by M. Cyril Grand Eury from the silicified Carboniferous deposits of St. Etienne, in France. Some of these exhibited a remarkable cavity at the apex of each orthotropous seed, enclosed within the testa and separating the latter structure from the nucleus. This cavity appeared to M. Brongniart to have received into its interior the pollen-grains, since he found within it, in several instances, small foreign bodies which bore a close resemblance to true pollen-grains. The author has discovered seven similar though distinct species of seeds in the lower Coal-measures of Lancashire and Burntisland. These seeds he described in detail. The most striking of them is one to which he has assigned the name of *Lagenostoma oviformis*. This is a small suboval seed, containing an almost spherical nucleus. Its external covering consists of a hard dense cellular testa. This has had an opening in it corresponding to the exostome of an ordinary seed, and which constituted the orifice of a flask-shaped cavity, having a short narrow neck, and the base of which rested in its normal state upon the upper extremity of the nucleus. This "lagenostome," as the author proposes to designate the cavity, is bounded by a bottle-shaped membrane composed of a single layer of short prosenchymatous cells, and contained a central mass of small delicate parenchymatous cells, which appear to have entirely filled the cavity when the seed existed as an ovule. This lagenostome is enclosed within a second and denser membrane, also composed of prosenchymatous cells, but of larger size than those constituting the membrane of the lagenostome. The outer investment hangs down from the inner margin of the micropyle like a festooned tent, and becomes merged at its lower margin, as is also the case with the lagenostomal membrane, with a very especial membrane enclosing the nucleus. On making transverse sections of this part of the seed, the tent-like membrane just described is seen to exhibit ten crenated curves, the concavities of which are directed outwards. Between these concavities and the external testa a delicate but large-celled parenchyma seems to have formed a feeble bond of union between the two, whilst in the centre of the circle of which each crenulation is a portion is a black speck, which has either formed an intercellular canal or a pillar of cellular tissue more dense than that surrounding it. The crenulated curves referred to have corresponded with the undulation in the wall of the lagenostome. In two examples the interior of the latter organ contained several small bodies in close contact with the nucleus, and which exhibited every appearance of being pollen-grains. The nucleus itself is enclosed in a thin special membrane, full of small angular spaces, which look as if they had been occupied by crystals.

To a second similar, yet very distinct seed, the author has assigned the name of *Physostoma elegans*. In it the apical extremity of the nucleus contracts into a mammillated projection, which appears to be pushed up into the base of the lagenostome, which thus looks like a bladder half full of fluid resting upon and overhanging the end of a soda-water bottle. In this seed the lagenostome and nucleus are further enclosed in a special uniform prosenchymatous layer of some thickness, and which in all probability was again invested by some exotesta that is not preserved in the solitary seed of this species hitherto met with.

Another species of seed the author designates *Conostoma*; and a fourth, of a somewhat similar type, was obtained from Burntisland.

A fifth species constitutes a very distinct type, having a dense parenchymatous exotesta, which has obviously been like that of the *Salisburia*—*i. e.* capable of drying and shrinking, and thus giving to the section of it an irregular outline. To this seed the author gives the name of *Malacotesta oblonga*. Some remarkably fine specimens of *Cardiocarpon* were also shown, exhibiting a central subconical nucleus, each lateral margin of which swelled out into a rounded and prominent moulding. This was enclosed by a delicate cellular endotesta and a much denser exotesta, both of which were prolonged superiorly into a long slender beak-like appendage containing the micropyle. A remarkable feature of this seed was the large size of the cells of the nuclear parenchyma. Like the *Trigonocarpon*, to some peculiarities in the structure of which the author directed attention, all these seeds have obviously been gymnospermous; and, from a recent communication presented by M. Brongniart to the Academy of Paris, there is reason to believe that all the seeds possessing a lagenostome may have been Cycadean.

ZOOLOGY.

[For Dr. Sclater's Address see page 85.]

On the Primary Divisions of the Chitonidæ.
By PHILIP P. CARPENTER, *B.A.*, *Ph.D.*

The writer showed that there were two parallel groups, the articulated or perfect Chitons, and the non-articulated or imperfect Chitons. Each of these were naturally divided again into regular and irregular forms, and these again into family, generic, and subgeneric series. The palæozoic Chitons were all imperfect, and culminated in the Carboniferous period; very few are now living. The neozoic epochs gradually developed perfect Chitons, which culminate at the present time. The writer sought information as to unusual forms, recent or fossil.

On the Nervous and Generative Systems of the Crinoidea.
By Dr. W. B. CARPENTER, *F.R.S.*

On the Occurrence of Moa-bones in New Zealand. *By* Dr. HECTOR, *F.R.S.*

On the Classification and Affinities of the Rotifera. *By* C. T. HUDSON, *LL.D.*

The author commenced by discussing Ehrenberg's classification of the Rotifera, and showed by the help of illustrations and diagrams that its fundamental principles were erroneous, for it was based on a supposed structure of the trochal disks which really did not exist, on a forced interpretation of the term "lorica," and on the presence, absence, and number of certain red spots, which Ehrenberg always took for granted to be eyes, but which were not always so ; moreover, those that really were eyes were often present in the young animal, but invisible in the adult.

Ehrenberg's symmetrical system erred in both directions. It brought together widely dissimilar forms, and separated those that were intimately connected. The rival systems of Leydig and Dujardin were then discussed, and dismissed as inferior to Ehrenberg's ; though it was pointed out that each naturalist had contributed a happy idea in making his unsuccessful attempt—the former having brought into prominence the great value of the foot as a characteristic for classification, and the latter having hit upon the excellent notion of dividing the Rotifera into orders according to their means of locomotion.

Dr. Hudson then proceeded to re-classify the Rotifera according to a system of his own, in which he availed himself of the labours of Ehrenberg, Leydig, Gosse, &c., and arranged the creatures by means of their nervous, nutritive, and vascular systems.

The true position of the Rotifera was then discussed. It had long been disputed whether they should be placed among the Vermes, or whether they should be ranked as very humble members of the Arthropoda. Leydig and Gosse had always maintained the latter opinion, while the former was upheld by Cohn, Vogt, Huxley, &c., and followed by the majority of modern naturalists. The various arguments against the alliance of the Rotifera with the Arthropoda were severally met, and it was shown how recent discoveries had tended to lessen their value—notably that of *Pedalion mirum*, the six-legged rotifer, discovered by the author in a pond near Clifton four years ago.

Professor Huxley's reasons for considering the Rotifera to be permanent forms of Echinoderm-larvæ were then discussed. The Professor had asserted that the Rotifera were in their forms divisible into two great groups, that, as far as it was known, the one was monœcious and the other diœcious, and that a corresponding division of form and sexual arrangements existed among the Echinoderms in their larval state. "It is this circumstance," says the Professor, "which seems to me to throw so clear a light upon the position of the Rotifera in the animal series . . . . and hence I do not hesitate to draw the conclusion that the Rotifera are the permanent forms of Echinoderm-larvæ."

Dr. Hudson pointed out that his own discoveries had destroyed this argument, for he had found the male forms of *both* groups.

It was shown how closely *Pedalion* resembled one of the Entomostracous larvæ, and how it was connected by other aberrant rotifers with those of the ordinary type; and the conclusion was drawn that, if the Rotifera were arranged according to their complexity of structure, it would be found that at the lower end of the scale they would, through the *Philodines*, be allied to the worms, and would then form a gradually ascending series till at its upper end, through *Pedalion*, they would be linked on to the Entomostraca.

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*On certain Neglected Subjects of Ornithological Investigation**.

By Alfred Newton, *M.A., F.R.S., V.-P.Z.S., &c.*

To the author it seemed that ornithologists have of late been getting into certain well-worn ruts to the abandonment of other tracks which equally deserve travelling upon. He has recently had to "take stock" of our ornithological knowledge, and finds that the result on the whole is gratifying—some branches of the study having received much encouragement since the new views of Evolution were promulgated, but others have remained *in statu quo antè*. Among the former are the Differentiation of Species and Geographical Distribution; but Developmental Osteology (the department of science which in this country Prof. Parker has made his own) still remains one in which the plenteous harvest has but few reapers, and is earnestly recommended to young ornithologists. Descriptive Anatomy has fair prospects; and Fossil Ornithology receives as much attention in Britain as can be expected from the scarcity of ornitholites; but Pterylography is still far too little thought of.

The greatest falling off appears to be in Observational Ornithology, owing to the out-of-door ornithologists trying each to find out every thing for himself, instead of starting from the discoveries of our predecessors. The want of progress is most plainly shown by observations on Migration, which are of exactly the same kind as in Gilbert White's time, though there was then a special object now not needed. No tabulation of such as have been made has been attempted, except by Von Middendorff (Die Isepiptesen Russlands. St. Petersburg: 1855); and consequently what may come of it cannot be said. Partial migration, which is most likely to reveal the cause of birds' movements, is still much neglected; and no one in this country has tried to show the routes by which they migrate, a subject last year ably treated by Palmén (Om Foglarnes flyttningsvägar. Helsingfors: 1874). The step in advance taken by Knox more than twenty years ago has hardly been maintained by other British observers, and thus very little has been done since White's time. We cannot guess at the faculty by means of which migration is so unerringly performed. We have no observed facts to urge against Von Middendorff's hypothesis, wild as it seems, that birds may be aware of the position of the magnetic poles, so as to steer their course accordingly; while Palmén's supposition as to "experience" affording a key to the mystery is insufficient; for experience can only mean a recognition of landmarks, which is impossible in the case of birds which travel by night or cross at one stretch 1000 miles of land or sea.

The so-called "Laws of Plumage" have also been almost entirely neglected of late. Incidental remarks on Moulting are found here and there; but no connected series of observations on the subject generally, which might be profitably investigated by those who have constant access to zoological gardens, while those who keep tame birds might also afford efficient aid.

The period of Incubation is a subject on which, with but very few exceptions, we are quite ignorant. When it differs in two species so nearly allied as the Pheasant and the Barndoor-fowl, we may be sure that some important cause exists which has hitherto escaped us; and the effects, if any, of atmospheric temperature on the development of the chick are equally unknown. Under 200 species breed in Britain, but the period of incubation has not been accurately ascertained in 20; and with respect to foreign birds our ignorance is still more profound.

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The author stated that he might easily extend his remarks to other heads, but perhaps this was enough. He looked rather to those who had not yet adopted any special branch of research to prosecute the inquiries he recommended than to ornithologists of experience who were occupied in their own line, though he doubted not they would countenance the view he took.

On Instinct and Acquisition. By D. A. Spalding.

Anatomy and Physiology.

[For Professor Cleland's Address see page 134.]

On a new Method of taking Photographs of Microscopical Objects, devised by Mr. Hugh T. Bowman. *Illustrated by Micro-photographs of Anatomical Preparations. By* Henry B. Brady, *F.R.S. &c.*

The instrument exhibited and described consisted of a small oval mirror of speculum metal, set in a brass cap to fit over the eyepiece of the microscope at an angle of 45°, the microscope to be placed horizontally. If used for drawing (instead of the ordinary camera lucida), the reflected image was received on a sheet of paper, the side light being shut out by the employment of a box blackened inside or a thick cloth. For photographic purposes an ordinary photographic camera was arranged, with a hole in the base instead of the end to receive the microscope tube, the plate-holder being in a horizontal position. The exposure required for wet collodion plates, even with high powers, was stated to be very short.

On some Physiological Effects of various Drinking-Waters.
By W. J. Cooper.

In 1870–73 M. Wurtz, the Dean of the École de Médecine in Paris, presented to the French Academy of Science two important papers by M. F. Papillon. In those papers it was shown that the phosphate of lime in bone is capable of being replaced to a considerable extent by the phosphates of strontia, alumina, and magnesia. The first experiments of M. Papillon were commenced on Monday, September 6th, 1869. He took a young pigeon, shut it up in a cage, and fed it with wheat rolled into a fine paste, and mixed with some phosphate of strontia and a solution of chlorides, carbonates, sulphates, and nitrates of potash in the proportion of 1½ gramme to the litre of distilled water; a small quantity of hydrochloric acid was also added. On the 1st of April, 1870, the pigeon was killed. An analysis of the bone-ash showed:—

Lime	46·75
Strontia	8·45
Phosphoric Acid	41·80
Phosphate of Magnesia	1·80
Residue	1·10
	99·90

Another pigeon on the same date as the preceding was supplied daily with a solution of phosphate and carbonate of magnesia and distilled water. Killed on the 4th of April. The analysis of bone-ash showed:—

Lime	51·76
Magnesia	1·81

On the 16th September, 1869, a white rat, six days old, was treated daily with a decigramme of phosphate of alumina in a litre of distilled water, with rice and gluten. On the 29th November, 1869, the rat died suddenly of convulsions. A *post mortem* examination showed inflammation of the intestines, attributed to the mechanical effect of nodules of phosphate of alumina. The rat was boiled in distilled water, and then boned. The bone-ash contained:—

Lime	41·10
Alumina	6·95

On the same date as the first rat, a little rat of the same litter was put under the same conditions, except that in place of phosphate of alumina, phosphate of magnesia was administered. This rat was killed on the 25th November, 1869, apparently quite healthy. The bone-ash was found to contain:—

Lime	46·15
Magnesia	3·56

May 21st.—Six chickens, just hatched, were taken; one killed immediately; others fed with rice, cooked in distilled water, with phosphate and carbonate of magnesia added to the ordinary salts in the water they drank.

June 28th.—Rice replaced by wheat, cooked as the rice.

The five chickens were killed at different periods.

	Ash showed in analysis	
First, 4th July	Lime	53·45
	Magnesia	0·83
Second, 12th July	Lime	51·59
	Magnesia	0·90
Three others, 10 days later	Lime	50·51
	Magnesia	2·01

There were only inappreciable traces of magnesia in the bones of the chicken killed at the moment of its birth. The bones of all these animals had preserved their ordinary aspect and physiological properties, and there was no disturbance of the normal functions of the system. Bone-ash, as is known, consists of phosphate of lime, with about two per cent. of phosphate of magnesia, and more or less carbonate of lime. The full importance of these experiments does not seem to have been fully appreciated. It is not only shown that the food which is eaten affects the composition of the bones, but that mineral matter in dilute solution is capable of being assimilated. The experiments are in fact experiments on different kinds of artificial drinking-waters, and illustrate how profoundly the bodies of animals are influenced by the mineral constituents of the water which they drink. They seem to show that the effect of altering the composition of the water-supply of a community might involve questions of vast importance to the organic structure of the human body, if the very composition of our bones is affected by the quality of the water. If the water contains lime, lime may be taken up, and would appear as phosphate of lime in the bones; if strontia, as phosphate of strontia; if magnesia, as phosphate of magnesia. If by any combination of circumstances these salts should be deficient, the bones would be imperfectly supplied with mineral matter. It is said that such instances have occurred in Holland in districts where the inhabitants can only obtain rain-water for drinking-purposes. This fact, probably combined with an absence of lime in their food, occasions a softening and distortion of the bones of the body. By varying a water-supply it might be possible to alter the physical organization of a population, and in future ages, from the examination of the bones of bygone generations, the character of the water they were in the habit of drinking might possibly be deduced. So much attention is now directed to organic impurity in drinking-water (a defect which can be completely remedied by careful filtration), that the inorganic impurities have been almost overlooked, although there are numerous instances where serious consequences have arisen from the incautious use of deep-spring waters. Some time ago at Hendon, in Middlesex, an artesian well was bored to supply the water necessary for some valuable horses which were being reared there. The water was bright looking, pleasant to the taste, and quite free from any organic impurity; the foals, however, who drank the water soon died, and the whole stud were seriously affected with diarrhœa. Professor Way, one of the Royal Commissioners on Water Supply, analyzed the water, and it was found to contain sulphates of magnesia and soda in considerable quantity. On discontinuing the use of the water the disease was arrested. A similar case occurred at Rugby: but in that instance human beings were the sufferers. The water from an artesian well free from organic impurity was hailed with satisfaction at its brightness: the community, however, were attacked with diarrhœa, caused by the sulphate of magnesia or Epsom salts present in the water, and the supply had to be discontinued, as there is no known method of freeing the water from sulphates. The opinions of some leading authorities on water-supply have undergone considerable modification recently. A few years ago Dr. Frankland returned all solid matters in water as impurities in the analyses he made. The author was therefore much surprised to hear him recommend as a supply to a district containing 14,000 inhabitants a water proved by analysis to contain 12½ grains of anhydrous sulphate of magnesia per gallon, equal to 25 grains per gallon of Epsom salts. This evidence was given last session before a Committee of the House of Commons. Dr. Frankland stated that it was absurd to say that a water containing such a quantity of Epsom salts could be objectionable from a dietetic point of view. Fortunately for the health of the people the Parliamentary Committee refused to allow the district to be supplied with the Epsom-salt solution. The water of St. Ann's Well, at Buxton, the slight purgative quality of which is considered one of its merits, contains an amount of magnesia equal to 13 grains of Epsom salts per gallon. It is known that goitre and other throat and glandular affections, and even idiocy, have been attributed to inorganic salts in drinking-water. We know that the human system is easily deranged by a change in the drinking-water. The spa and chalybeate waters at the favourite places of resort have been renowned for ages for their medicinal virtues. If the entire organic structures of the human body are liable to alteration when excess of mineral matter is introduced into the system, it is essential that health-seekers at these medicinal springs should place themselves under medical supervision. And one of the first considerations in the inauguration of a water-supply should be to ensure a perfect freedom from excess of any mineral except those comparatively harmless ingredients—chloride of sodium and carbonate of lime.

Further Researches on the Physiological Action of the Chinodine and Pyridine Bases. *By* Prof. DEWAR *and* Dr. M'KENDRICK.

On the Origin of the Lymphatics.

By DRS. GEORGE *and* FRANCES ELIZABETH HOGGAN.

Our knowledge of the intimate structure of the lymphatic system commences with Von Recklinghausen, the discoverer of the beautiful silver method of staining tissues. As it was impossible to speak in a short paper of the nature of the lymphatic radicles in all tissues and in all classes of the Vertebrata, the authors exhibited drawings carefully executed, by the aid of the camera lucida, of the following:—

1. Lymphatics and their radicles in the voluntary muscles of mammals.
2. Lymphatics and their radicles in the involuntary muscles of Batrachians.
3. Lymphatics and their radicles in the skin of fishes.
4. The development of lymphatic vessels in the embryo.
5. The development of lymphatic radicles at all ages.

The development of the lymphatic radicles is simply that of fixed connective tissue. The gradual development of embryonic cells into permanent connective tissue was described by means of drawings, which showed the distinct multinuclear, protoplasmic, embryonic cells in the early embryo, forming the first stages of the cells of a basement membrane. The embryonic cells place themselves in position, grow larger, till each nucleus is able to separate with its own particle of protoplasm to form an independent, although irregularly shaped flat cell, the so-called branched or lymphatic cell of the ground substance; in other words, the connective-tissue cell of a basement membrane. The varieties of form which these cells now assume are unlimited. At one spot in the same preparation the authors can see them pressing together to form the flat and irregularly hexagonal or round cells of the endothelium from (and lying upon) the cells of the basement membrane. At another place they have seen them elongating into fibrous tissues, such as are seen in the skin or in the wall-tissue of an ovarian cyst. When several months ago they discovered that, after rubbing epi- or endothelium off the surface, and treating the thus exposed surface with silver, there were presented to notice the cells of lymphatic ground substance, they (having verified this on several structures) supposed they had discovered that basement membranes were really lymphatic membranes. Before, however, they had carried their investigation much further, they found that Dr. Debove, of the College of France, had a few months before arrived at the same conclusion in regard to the basement membrane of the epithelium of the respiratory and alimentary tracts, and that Dr. Slavianski had done the same in the case of the lining of the Graafian follicle. They had, however, discovered that the basement membrane under the human epidermis had the same significance, which Debove had only suggested as probable, but had been unable to demonstrate. While continuing their investigations, they found, after stripping this thin layer or supposed basement membrane from the inside of the wall of an ovarian cyst, an identical structure underneath; and the same process could be often repeated with always the same result. Thus they were led to see that, these several sheets being identical with each other and with basement membrane, the so-called lymphatic ground substance was formed of the cells of connective tissue, of which basement membrane was itself composed. But just as the cells of basement membrane have been called lymphatic cells, so were the cells of these different layers quite as much lymphatic cells; and found as they are in all tissues, they constitute the radicles of the lymphatic system. The shape and position assumed by these cells depend on the form of the tissue proper of the organ in which they are found; separating the tissues proper from each other, while they are largely connected between themselves, they form nutrient channels, by means of which the tissues proper may supply themselves from the liquid pabulum which passes along the chains of these connective-tissue cells or lymphatic radicles.

The lymphatic circulation begins in this manner. The branched cells which we see depicted in the drawings of all careful observers as lying alongside of the capillaries and forming the tunica adventitia of small vessels form, the authors believe, the proximal points of the nutrient lymphatic system to the blood-vascular system. From these proximal cells the liquid pabulum is passed on into other similar cells, with which they have innumerable anastomoses; and the process thus continued through innumerable intricate networks of anastomosing lymphatic radicles or connective-tissue cells, we have, finally, a joining of these cells with lymphatic capillaries or small sinuses, carrying the now effete liquid pabulum (now called lymph) into the trunks of the lymphatic system and thence into the blood.

The authors believe that, as the seat of nutrition has been formerly removed from the smaller blood-vessels into the capillaries, so must we now further remove it from the capillaries into the network of anastomosing connective-tissue cells or lymphatic radicles. Nor is this hypothesis of nutrition connected with or depending on an hypothetical position or condition of the cells themselves. The authors have traced the cells of the tunica adventitia of a vein until they joined together in opening into a small lymphatic vessel; but it is from the drawings of others that they prefer to prove this arrangement. Take, for instance, some of Klein's beautiful plates in his monograph on the lymphatics; we there see, in his drawing No. 34, the branched cells extending by anastomoses amongst themselves, between the smaller vessels of the blood and lymphatic systems.

Upon the more or less permeable or channelled condition of those cells the authors did not dilate, although they pointed out that the well-known hollowing out of these branched cells to form new capillaries at the blood-vascular end is probably only the result of a demand for an excessive supply of liquid pabulum from the tissues nearer the lymphatic end of the chain, the cells at either end being capable of forming a blood or lymphatic vessel, by the process of hollowing out so often described by histologists, as the necessity of the case may demand.

They next considered the development of lymphatic vessels in the embryo. Dr. Klein, in his work already quoted, draws and describes the formation of endothelium by vacuolation of cells—that is, cells becoming hollow and greatly enlarged, and their wall subsequently becoming divided off into numerous endothelial cells. He further predicts that it may subsequently be found, from the arrangements of these vacuoles in relation to each other, as seen by him in natural and induced inflammation, that they may ultimately open into each other, and thus form lymphatic channels. This very natural prediction of his the authors have seen fulfilled—not, however, in inflammatory conditions, but in the embryo itself. They have observed this process in its different stages, from the commencement of the formation of a vacuole to the junction of two or three fully formed vacuoles with each other and with the termination of an already formed lymphatic channel. While, however, they agree with his description of the process of formation of vacuoles in many cases, they do not consider it to be invariably applicable. In other cases it appears to consist of a circular hollowing or sinking down of the basement membrane from the surface endothelium, the lining cells being formed by multiplication and compression of the cells of the basement membrane, thus forming a pavement of cells for the lymphatic sinus. This mode of development of lymphatic vessels the authors do not consider as general, but applicable only to such conditions of excessive vital stimulation as are found in the embryo and during inflammation, the ordinary process of such formation being similar to the same in blood-vessels—namely, a gradual enlargement of a lymphatic radicle by distention and addition of other cells, as the necessity for enlargement shows itself, until a comparatively large lymphatic channel is formed.

On Protoplasm and Adipocere. By D. J. GOODMAN.

On the Preservation of the Bodies of the larger Animals for Dissection. By F. GREENWOOD.

Although many suggestions have been made and methods described for the preservation of animal carcases for dissection, yet few seem to have been carried out in practice, at any rate so far as regards the larger animals. In the case of the ordinary subjects of veterinary anatomy, the abundant supply renders any attempt at long preservation needless, as a whole subject can well be sacrificed for the sake of some special region or organ.

But when some uncommon but bulky specimen falls into the way of an anatomist, he must either content himself with a very cursory examination of the general disposition of the parts, or select some special points for investigation, and leave the rest. He must, besides, be prepared to devote all his time to the work, or the opportunity is lost.

The latter consideration, in the case of those who can only devote their leisure or a portion of their time to such work, frequently prevents any attempt to prosecute what might be most interesting researches. Nevertheless tolerably easy and simple means may be indicated by which a body can be preserved indefinitely in a state fit for dissection, so that the work may be either pursued or laid aside as circumstances determine.

It has been suggested that, as we have been tolerably successful in dealing with the carcase of a young elephant from last winter until now, some account of the mode of procedure may be of interest to those who have a taste for such work.

The animal was purchased by the Council of the Leeds Philosophical and Literary Society, and most liberally handed over to their Curator, to be dealt with as he considered best; and it is owing to the facilities freely furnished by them that the work has been continued.

The animal, which died about the 13th of December, was received on the 16th, in a very fresh condition, owing to the cold weather which set in about that time. It was deposited in an open yard, but the next day a light wooden shed was erected over it. At this time the possibility of making a detailed and leisurely dissection was not contemplated. The dissector only hoped to make out a few of the principal points of interest; so that the first steps of the dissection were not so exact or well arranged as they would otherwise have been. The abdomen was opened, and the stomach, liver, spleen, and intestines were removed. The hide being wanted for the purpose of tanning, the carcase had to be flayed, not without some injury to the superficial structures. At this time the cold was very intense, and the work of dissection consequently both painful and laborious, crystals of ice forming under the knife.

However, the work was continued, as the possibility of a sudden change in the weather, and consequent speedy decomposition of the carcase, was kept in mind, the elephant having the reputation of being especially prone to rapid putrescence after death.

The pectoral and axillary regions of the left side were dissected, and the front and left side of the neck.

At this time nothing was done to preserve the body with the exception of sprinkling it with spirit, which was found to facilitate the dissection by preventing the rapid freezing of the exposed parts, which was annoying. The cloths with which it was covered were also wetted with spirit.

Finding that progress was very slow, and perhaps also entering more into the work than at first, it occurred to us to try the effect of the arsenical solution which is used in the School of Medicine to preserve subjects for the usual period of dissection, hoping to delay the progress of decomposition for a time.

We therefore inserted pipes into the abdominal aorta, and injected a quantity of the fluid both upwards and downwards. It ran very freely, and penetrated the most distant parts, although a good deal escaped from various points. With the view of better preserving the brain, a quantity of methylated spirit was injected by the carotid artery.

Finding that the subject seemed to keep very well, and the great desirability of a detailed and careful dissection becoming more and more apparent, the possibility of a permanent preservation of the portions of the carcase began to be considered.

We have for some time been in the habit of preserving such things as dissected limbs, which have been injected with the preservative solution, for considerable periods, by keeping them in a closed box with a little spirit sprinkled over them occasionally, so as to keep up a spirituous atmosphere in the box.

This plan it was decided to adopt with the elephant. A large box was prepared, and ultimately a second, lined with lead and with closely fitting lids.

Each fore limb, when separated, was again injected with the fluid and afterwards with dilute spirit; and the injection, sometimes with one solution and sometimes with the other, was repeated several times at intervals of a few days. The parts were covered with cloths wetted with spirit, and laid in the box. The hind limbs were kept attached to the pelvis, and were treated in the same way. The head was at first immersed in dilute spirit, and kept in a tub by itself. The viscera were preserved, as usual, in fluid.

From this time, which was about the middle of January, until now the parts have remained perfectly sweet, sound, and natural in appearance, the muscles retaining their natural colour, and the other tissues fully maintaining their distinctive characters. The brain, however, was found not to be well preserved, though the cerebellum and medulla oblongata were tolerably perfect. This, however, was not examined until after six months had elapsed.

Owing to various causes, the dissection has been going on very slowly and with repeated short interruptions; but the part under dissection has been simply rolled in a cloth which is kept moist by wetting it with dilute spirit, the use of the spirit being rather to prevent the water from producing too great flabbiness and mould than directly to preserve the part. A dilute solution of a mixture of carbolic acid, glycerine, and methylated spirit is also very useful to wet the cloths with, as it is highly antiseptic; and in the summer an outer covering of Mackintosh cloth has been found convenient to check evaporation.

If not kept wetted the parts soon dry up, and are apt to become covered with a whitish efflorescence, which is difficult to remove.

I am inclined to attribute the success in great measure to the repeated injections, a few days interval being allowed between each; thus the tissues had time to become thoroughly impregnated with the fluid; and it is to that, rather than to the special virtues of the solution, that the result is due.

It is thus apparent that a tolerably bulky animal may be preserved for dissection at leisure with a moderate amount of trouble and expense—all that is needed beyond the necessary anatomical knowledge and instruments being a sufficient quantity of the arsenical fluid (which is quite cheap), a gallon or two of methylated spirit, and a tolerably well-closed box or case in which to deposit the subject.

On Vegetarianism. *By* C. O. Groom-Napier.

Bearings of "the Conservation of Force" on Life. *By* P. Hallett, *M.A.*

The object of this paper is to consider the modern theory of the conservation of force in connexion with the phenomena of life.

The author holds that these phenomena do not conform to it, but that they rather indicate that life, considered as a natural cause, whatever the nature or essence of that cause may be, has within itself a power of self-propagation and renewal. Though it borrows its materials from the physical universe, it confers on them the vital powers, both general and specific, that they possess through organization.

On some new Researches on the Anatomy of the Skin. *By* Dr. Martyn.

The object of this communication was to make known some facts in the anatomical structure and growth of the cuticular layer of the skin. In a recent paper the author had described this with reference to disease, and he now had to confirm the view which those appearances led him to predict as holding good for ordinary and healthy epithelium also.

Twelve years ago Max Schultze observed that the lowest of the cells forming, in many layers, the cuticle were often covered with spines ("Stachel") or grooves ("Riss"). His brother confirmed this in fishes, and other observers had done so in many diseases of the skin. The subject attracted little notice, and had scarcely even now reached our English text-books.

It was in endeavouring to make out the real nature of so strange a structure that the author, by employment of unusually thin sections, staining, and the highest available powers of the microscope, had discovered that the cells which appeared "spinous" or "echinate" when isolated from their connexion, if they could be at any time seen in single layers, were simply united together by delicate bands. These are so constantly seen broken across that they assume the form of tubercles or "prickles." As repeated observation confirmed this, the name "conjoined epithelium" had been proposed for this form or stage in cell-life as here exhibited.

These observations, of which drawings were engraved in the Number of the Monthly Microscopical Journal of the present month, were made on cancer of the skin, in which the cells fortunately become monstrous.

Now the author was in a position to say that the "conjoined" epithelium was also to be found in (1) human skin, (2) the front of the eye in the pig, (3) the lips of at least one fish (*Zeus faber*). The sturgeon was just now under investigation.

The difficulty of making the structure clear in a healthy animal cuticle was (1) the intense cohesion of these very cells, so that, in trying to stretch, one usually breaks the uniting bands; (2) the necessity for using a high power, the $\frac{1}{12}$, with 800–1000 diameters, being required to make sure of the nature of the bands.

The interest of the subject lies in this direction. All the cells of which living things at any moment consist were produced by division of a parent, either into two equal parts (fissiparous) or by budding off a small bit (gemmiparous). Epithelial cells grow so too; and in "conjoined" epithelium we, so to say, catch the division process lingering on. Many cells divide like an hour-glass; but here the points are very numerous. Protoplasm, of which cells at first consist, varies constantly in form, as the amœba, or the white-blood cell. While alive *in a formative sense* it moves. The old outer firm wall or shell of "matter" which forms around cells, and which we call cell-wall, has ceased to have this formative life, whatever functional powers it has. Cells of many striking shapes are found in the organic world—star-shaped, spindle-shaped, caudate, and so on. In the early discoveries of cell-growth (soon after Schwann, 1836), innumerable mysterious vital powers were attributed to cells, amongst which was that of projecting processes, long wandering arms pervading intercellular tissue or other structures. As the author had endeavoured to show some years ago, the form of the cell is almost invariably the result of ordinary force. It is a form which the cell is forced to take, by dragging out of points at which it was in the act of dividing. This idea is now a familiar one, and the conjoined epithelium a good illustration. A fresh subject for investigation would be those cases in which cells are covered with ciliary processes, probably from splitting of hardened and formed outer materials.

On Vascular Plexuses in the Elephant and other Animals.
By L. C. MIALL *and* F. GREENWOOD.

ANTHROPOLOGY.

[For Professor Rolleston's Address see page 142.]

Note on the Ossuary at Rothwell, in Northamptonshire.
By JOHN BEDDOE, *M.D., F.R.S.*

This is a very large ossuary in the crypt of a church. There is a sort of tradition that the bones are those of men slain in some battle; but it is unworthy of notice. A few of the skulls were brought away three or four years ago by Sir William Grove, and restored to their place after being measured and described by Prof. Busk. Dr. Beddoe examined a different set of skulls, which he took indiscriminately from the heaps, only rejecting those which were clearly feminine. The average length of fifteen was 7·313 inches, the average maximum breadth 5·757 inches, the average index of breadth 78·7, varying from 72 to 87. The index of height was probably low. The average capacity of ten (measured with rape-seed and Busk's choremometer) was 1366·5 cubic centimetres, equal to a weight of 45·6 oz. for the true brain-substance, reckoning the sp. gr. at 1040, and allowing 4·5 oz. for the membranes and blood. This is a very low brain-weight, below even that of Dr. Boyd's series of paupers and lunatics.

Rhabdomancy and Belomancy. By A. W. BUCKLAND, *M.A.I.*

In this paper the author endeavours to show:—

1st. From personal observation that Rhabdomancy is still practised in England in certain localities, and that it is a survival of a very ancient superstition originating in the use of rods as symbols of power.

2nd. That the staff as a sceptre was probably a later form of the horn, which was thus used in very early prehistoric times, and in that character adorned the heads of gods.

3rd. That from this use of rods or horns arose a veneration for them as possessing the inherent power of healing disease and even of restoring life. Hence their use by magicians in all ages and countries, the chief instruments employed by them being a ring and a staff and a bifurcated stick.

4th. That these symbols conjoined are found in Egyptian, Assyrian, and Peruvian sculptures, and may be traced in some of the stone circles of Britain, and in the shape of Irish brooches or fibulæ.

5th. That from the belief in the magical powers of rods perhaps arose tree-worship, or at least such veneration for trees as is observable of the oaks of Dordona and of the Druids, the ash of Scandinavia, and, for some unexplained reason, more particularly of the hazel.

6th. That Belomancy or Divination by marked arrows, said to be of Scythic origin, was practised in Babylon, Judæa, and Arabia, and that traces of it may still be found in folk tales of Russia and Siberia.

7th. That the mode of using these arrows had a strong resemblance to the very ancient custom of casting lots, common to all peoples, ancient and modern, the "Hwiting Treow" of the Anglo-Saxons being still used by the Hottentots.

8th. That the invention of lots and dice as well as that of the divining-rod is ascribed to Hermes or Mercury, identified with the Woden of the north and by some writers with the Indian Buddha.

9th. That a strong resemblance exists between the implements of magic and the ancient alphabets, also the reputed invention of the same god or gods.

10th. That many of the signs or letters forming the Archaic-Phœnician alphabet are found in the rock-sculptures of Peru, thus adding one more to the many proofs of a communication existing between the hemispheres in prehistoric times.

11th. That the arts of magic and divination were not of Aryan origin, but a remnant of that Turanian or pre-Aryan faith which once overspread the world.

12th. That this is proved by their present existence among aboriginal non-Aryan races, and may perhaps even be used as a test of race; so that those who in Somerset and Cornwall are said to possess the power of divination by the rod, may possibly have some remote affinity with the aboriginal inhabitants of Britain.

On the Indians of the North-western United States. *By* Colonel CARRINGTON, *LL.D.*

On Prehistoric Culture in India and Africa. *By* HYDE CLARKE.

Calling attention to the author's philological investigations as to the evidence of the successive migration and distribution of languages in Asia, Africa, North, Central, and South America, and in some cases in Australia, he proceeded to give the result of later special investigations as to the community of culture in India and Africa. For this purpose Koelle's African vocabularies were used, with those of Dr. W. W. Hunter, Col. Dalton, and Sir G. Campbell for India, but excluding the Tibetan, Dravidian, and Sanskrit. Thus the materials were chiefly derived from Bodo, Dhimal, Kooch, Garo, Savara, Miri, Naga, Karen, Kami, and Kol, races which certainly had exercised no influences of commerce or civilization in Africa within the historic period. Besides weapon-names elsewhere referred to, Town, Canoe or Boat, Tree, and Leaf show a community. The author then showed how the Indian words for salt were reproduced in Africa, as:—Naga, *matse*; Miri, *alu*; Kol, *bulung*; Kooch, *nun*; Kami, *maloi*; Bodo, *kara*; Savara, *lusi*; Karen, *ithah*; Gondi, *sabbar*. The facts he held to prove that the earliest savages had made themselves acquainted with the properties of salt, and carried this knowledge with them throughout the world in their migrations. The names of the domestic animals are recognizable; but those for elephant seem to show, as might be expected from geological testimony, that this animal being then most widely distributed was well distinguished. The philology of the aboriginal languages of India could only be effectually studied from those of Africa; and the author suggests that it would be a great advantage if some of the missionaries of the two regions could interchange stations.

Further Note on Prehistoric Names of Weapons. By HYDE CLARKE.

This was in continuation of a note laid before the British Association in 1873, showing, in connexion with the distribution of weapons, that there was a community of aboriginal names in the prehistoric epoch as there is now. The author stated that these results were confirmed since then, and since the publication of his 'Researches in Prehistoric Comparative Philology,' by the examination and classification of a larger body of facts. The names for arrow, dart, spear, sword, knife, and axe were found to present common forms in Asia, Africa, Australia, North America, Central America, and South America. The philological facts show a series of influences, so far as Australia is concerned, operating from the Old World. In conformity with Col. Lane Fox's conclusions, the names for the hoe and other tools are found to be allied with those of weapons, showing that the same instrument was used for tool and weapon.

On the Himalayan Origin of the Magyar and Fin Languages.
By HYDE CLARKE.

The author pointed out the relations of numerous languages in High Asia to the Ugrian, and remarked that the affinities of Magyar and Fin were strongest for the languages of East Nepaul. Among the Himalayan Ugrian were to be found Magyar and Hung; and the author suggested these as being connected with the invasion of Hungary. To harmonize the facts as to the connexion with this event of the Lesghians, Avars, and Khunzag of Caucasia, Mr. Hyde Clarke treated the chiefs as Lesghians (Vasco Kelarian) and the people as mostly Ugrian.

On the Ethnography of Scotland. By the Rev. J. EARLE.

1. *Aspect.*—That the Norwegians are like the Scotch in appearance and in several particulars of life is an ordinary and oft-repeated observation; but what gives this popular remark its value is this, that it is confirmed by the authority of the scientific observer. Early this year the author asked Dr. Beddoe whether he thought that the comparison of the Scotch to the Norwegians had any thing substantial in it; and the speedy result of that question was that he showed him a collection of large photographs which he had lately received from Dahlmann, the eminent Norwegian artist, as specimens of the various types in Norway; and almost all of them were, in his opinion, to be met with in Scotland.

2. *History.*—The Landnama states that the north of Scotland was conquered by Norsemen. The biographical and romantic Sagas present it as a habit of the Norsemen, when tired of home, to "harry west." The condition of Lincolnshire as compared with Denmark confirms the truth of this; and we may safely conclude that Scotland received those who left the south of Norway. From the more northerly fiords the outgoers occupied the Hebrides, which they called the Southern Isles (in their speech "Sundreyjar," a word which still lives on in the title of "Sodor and Man"). The Saxon Chronicle under 924 gives the composition of the population of Northumbria, which included the Lothians, in these terms—"ge Englisce, ge Denisce, ge Northmen." We know that many points of the west coast down to the Lake-district were occupied by Scandinavians. A passage quoted from Burton (History of Scotland) expressed that Norse superstitions lingered in Scotland down to a very recent date.

3. *Language.*—In the Scots language the most conspicuous and striking features are Norse; and this fact may now be considered placed beyond question by the admirable dictionary of Vigfusson, which every one with a moderate philological training can consult for himself. A list of words was given which strike our English sense as curious; and yet we, in thus judging of the Scots dialect, are using as a standard a language (English) which is itself deeply impregnated with Danish. Again, it is not just those words which seem most conspicuous that constitute the strongest evidence of the Norwegian element in Scotland. Such words as *bairn, gar, greet* (=weep), *ken, lax, speer,* speak for themselves; but such an auxiliary as *maun*

really merits deeper attention. So of other little words, and especially the preposition *til.*

4. *Summary.*—Our Danish and Norsk districts are the meeting-ground of the two great divisions of Gothdom, the Teutonic and Scandinavian. In England the Danish deposit has been much diluted, though spots there are, like Cleveland (so well described in Mr. Atkinson's 'Glossary'), where it is still in good preservation. The political line between Scotland and England protected North Britain from a like dilution, and made a place for the maturation of a language unparalleled in its own peculiar beauty, and especially as an instrument of lyric poetry.

On Recent Discoveries of Flint Implements in Drift-Gravels in Middlesex, Essex, and Berks. By R. EDWARDS.

On the Original Localities of the Races forming the present Population of India. By Sir WALTER ELLIOT.

The object of this paper is to show that the Hindus, although exhibiting many varieties of form and feature, were all referable to a common type, differing essentially from the Aryan, and equally distinct from a Mongolian and Negrito source. This normal character was deduced from Professor Huxley's Australoid type of mankind, the original seat of which was to be sought in Central Asia, whence from time to time, and often at distinct intervals, hordes have migrated into Hindústán, some through the passes of the Eastern Himalayas, others, as the later Dravidians, from the N.W., antecedent to the Aryan immigration. Later arrivals dispossessed earlier occupants, reducing them to slavery or amalgamating more or less intimately with them, but never losing the normal physical features of the race. Even the Aryans, when they came in contact with the despised Dásyus and Nisháадas (or monkey- and goat-faced tribes, as they contemptuously called them), could not help intermingling with them in some degree, both in the ordinary and inevitable course of sexual intercourse, and also by proselytism arising out of the relative circumstances in which they found themselves, as their own writings show.

Notice of a new Code of International Symbols for use on Prehistoric Maps. By* JOHN EVANS, *V.P.R.S.*

The system has been devised by a Committee appointed last year at the Congress of Prehistoric Anthropology and Archæology at Stockholm. The symbols are simple, and intended to denote the occurrence of dolmens, tumuli, and other objects of archæological interest, but are also susceptible of being made compound, so as to denote the particular character and even the approximate age of any monument. The Report of the Committee on which the paper was founded has been published in the 'Matériaux pour l'Histoire Primitive de l'Homme,' vol. vi. 1875 (Supplement).

On Recent Investigations in Cissbury Camp, Sussex. By Colonel A. H. LANE FOX, *Pres. A.I.*

On the Origin of the South-Sea Islanders. By the REV. WYATT W. GILL, *B.A.*

Mr. Alfred Wallace, in his admirable work on 'The Malay Archipelago' (p. 593, 4th edit.), has advanced the theory that the Polynesians are descended from a race which once overspread a vast submerged southern continent. As the land gradually sank, a few of the aborigines may have escaped to the tops of the loftiest mountains, around which subsequently coral reefs formed. Admitting that "Polynesia is preeminently an area of subsidence, and its great widespread groups of coral reefs may mark out the position of former continents and islands," the author still thinks Mr. Wallace's inference to be unwarranted; for:—

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* Published *in extenso* in the 'Anthropological Journal.'

1. Supposing that human beings inhabited this great southern continent at the period of the subsidence, and that a remnant escaped, the author believes that human life could not under such circumstances be sustained for any considerable time, as usually there is nothing edible on the tops of the Pacific mountains save berries, to say nothing of the difficulty, in most cases, of obtaining water.

2. The theory is utterly opposed to the native accounts of their own origin, which all point to the north-west.

3. The spread of the race can be accounted for on the basis of historical facts. In 1862 the author saw on Manuâ an open boat, which had accidentally drifted from Moorea, a distance of 1250 miles, and no life lost. A few months later on in the same year Elikana and his friends drifted in a canoe from Manibiki to Nukuraaeae, in the Ellice group (lying N.W. of Samoa), a distance of some 1360 miles. Half the party on board perished from want of food and water. In both these instances the drifting was from east to west, before the trade-winds. A far more remarkable event occurred in January 1858, during the prevalence of the *westerly* winds, when a numerous family of natives drifted from Fakaofo, in the Union group, north of Samoa, to Nassan Island, thence to Palmerston's Island, and finally to Mangaia, altogether a distance of 1250 miles in a south-easterly direction.

4. The colour, hair, general physiognomy, habits, character, and especially the language of the Polynesians, indicate a Malay origin. This cannot be accidental. It would be easy to give a long list of words identical or nearly so in Malay and Polynesian. The author believes that long ages ago the progenitors of the present race entered the Pacific from the south-eastern fork of New Guinea, but were driven to the eastward by the fierce Negrito race. The greatest distance from land to land, as they proceed eastward, would be from Samoa to the Hervey group, about 706 miles, which has been successfully traversed by natives in their fragile barks within the author's own observation.

Some Traditions of the Hervey Islanders. By the Rev. W. Wyatt Gill, *B.A.*

The classical word in the dialect of the Hervey group for "nether-world" is "Avaiki." The universe is conceived of as the hollow of a vast cocoa-nut shell, in the interior of which are many lands, the abode of gods and unhappy ghosts. Near the top of this vast shell, on the outside, are located their island homes. Rising one above another into immensity are at least ten separate heavens. Originally mankind and the natives of Avaiki interchanged visits through the opening at the top, which is now closed on account of the ceaseless depredations of the fairies.

The esoteric doctrine of the priests was, that souls leave the body ere breath has quite gone, and travel on to the edge of a cliff facing the setting sun. A large wave now approaches the base of the cliff, and a gigantic bua-tree covered with fragrant blossoms springs up from Avaiki to receive on its limbs human spirits, who are mysteriously impelled to cluster on its far-spreading branches. When at length the mystic tree is covered with ghosts it goes down with its living freight to nether-world. These unhappy ghosts are caught in a net, nearly drowned in a neighbouring stream, and then emptied out, shivering and terrified, in the presence of ugly Miru, mistress of the invisible world. Each newcomer to the shades is lured to drink a bowl of "kava" (*Piper mythisticum*), becomes stupified, and is then cooked and eaten by the hag Miru and her companions.

Such was believed to be the inevitable fate of cowards and of all who died a natural death. A nobler fate awaited warrior-spirits; their pleasant home was in the azure sky. In the month of August, when the coral-tree is in blossom, they assemble at the edge of a cliff overlooking the marae of the war-god. A mountain now springs up at their feet; the road to its summit is built of the clubs, spears, and stones with which they met their fate. They ascend with pleasure, and from the top leap into the expanse, where they float about as specks. Covered with garlands of sweet-scented flowers, they spend their time in dancing the war-dance and in reciting over and over again the brave deeds performed in life.

The practical result of this faith was to breed contempt for violent death, and to nourish a race of warriors who (like ourselves) despised bush-fighting.

*On the Recent Discovery of a Stone Implement in the Brick-earth of Erith, Kent**. *By* Dr. J. H. Gladstone, *F.R.S.*

The implement exhibited was a flint flake of very regular form, 5½ inches long and 2 inches broad, notched at the edges apparently from use. It had a small fossil *Echinus* at the broader end. It was picked up in the brick-earth pits at Erith, in the ancient valley of the Thames; but as it was found among the flints and other rubbish thrown aside by the workmen, it is impossible to say whether it came from the same beds that furnish the remains of the mammoth, rhinoceros, lion, &c., or from some higher and more recent stratum.

The Weddas of Ceylon.

By Bertram F. Hartshorne, *of the Ceylon Civil Service.*

The writer, after briefly referring to the accounts given by previous authors of this remarkable race, detailed the results of his personal observation of their habits, physiology, and language, dividing the whole tribe into the two classes of Jungle Weddas and Village Weddas. The former have retained more distinctly than the latter the essential characteristics of their autochthonous condition, still depending for their chief means of subsistence upon their bows and arrows, and passing their lives in the vast forests in the eastern part of Ceylon without any dwelling-places or system of cultivation.

Their skill in the use of the bow and the strength of their left arm was to be noticed, as well as the absence of any stone or flint implements among them. The influence of the civilized Tamil and Sinhalese races contiguous to the district which they inhabit has only in a very slight degree made itself felt; and their state of barbarism is indicated by the practice of producing fire by means of rubbing two sticks together, as well as by an almost entire absence of clothing, and the custom which they observe of habitually refraining from any sort of ablution whatever.

The copies of photographs exhibited showed them to possess features of no unintelligent type; but they wear an expression of extreme unhappiness, and one of their chief peculiarities is that they never laugh. It is probable that this circumstance is due to psychological causes rather than to any physical conformation.

Their intellectual capacity is extremely slight, and their power of memory defective. They are utterly unable to count; nor does their language contain any words to denote the numerals; and it is singular that, whilst their moral notions lead them to regard theft or lying or the striking of another as an inconceivable wrong, they are devoid of any form of religion, and also, apparently, of any religious sentiment, except in so far as that may be inferred from their practice of offering a sacrifice to the spirit of one of their fellows immediately after his decease, their idea of a future state being limited to the belief that they become devils after death, not, however, in the sense of the Buddhist theory of metempsychosis, but simply as one final and irresistible transformation.

The analysis of their language and of their songs or folk-lore was reserved by the author for a subsequent occasion; but he observed that their vocabulary largely consisted of words derived directly from the Sinhalese, and others indicated an affinity with Pali and Sanskrit, whilst there remained a considerable residue of doubtful origin. There is, however, an absence of any distinctly Dravidian element, and the language appears to bear no resemblance to that spoken by the Yakkas of Nipal. The author, after adverting to the danger of insisting too strongly upon the inferences which may be drawn from linguistic evidence in the determination of ethnological questions, drew attention to the interesting circumstance that the Weddas are the only savage race in existence speaking an Aryan language.

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* Figured and described in the 'Argonaut' for September 1875, p. 283.

On an Ethnological and Linguistic Tour of Discovery in Dardistan &c. *By* Dr. LEITNER.

On Anthropology, Sociology, and Nationality. *By* D. MACKINTOSH, *F.G.S.*

In this paper the author defends his statement of the results of observations in England and Wales which have already been given to the world in the 'Transactions of the Ethnological Society' (1861), 'British Association Report' (1865), and 'Anthropological Review' (1866). He believes that the inhabitants of different parts of England and Wales differ so much in their physical and mental characteristics, irrespectively of circumstances, that many tribes must have retained their peculiarities since their colonization of the country, by continuing in certain localities with little mutual interblending, or through the process of amalgamation failing to obliterate the more hardened characteristics. He describes the characteristics of a race he provisionally terms Gaelic, traces the differences between the inhabitants of South and North Wales, gives a minute definition of the physical and mental peculiarities of Saxons strictly so called (rejecting the term Anglo-Saxon as misleading), shows the difference between Saxons and Danes, follows Worsaae in believing that the Danes have impressed their character on the inhabitants of the north-eastern half of England, and tries to show that between the north-east and south-west the difference in the character of the people, irrespectively of circumstances, is so great as to give a seminationality to each division—restless activity, ambition, and commercial speculation predominating in the north-east, contentment and leisurely reflection in the south-west. He concludes by a reference to the derivation of the original inhabitants of New England from the south-west, and mentions the fact that, while a large proportion of New-England surnames are still found in Devon and Dorset, there is a small village called Boston near Totnes, and in its immediate neighbourhood a place called "Bunker's Hill."

Note on the supposed lost Language and Antiquity of the Kirghiz, or Buruts. *By* ROBERT MICHELL, *F.R.G.S., F.S.S., and Member of the Imperial Russian Geographical Society.*

This people, which formerly dwelt in the country of the Upper Yenissei, now occupies the valleys of the Thian-shan range, where, it seems, still more ancient representatives of the race dwelt before those of the Upper Yenissei, driven (in the 17th century) by the second series of Mongol Altyn Khans, and finally by Russian Cossacks, shifted their habitations. But while the Kirghiz of the Thian-shan are alluded to by Chinese chroniclers of the 13th century, those of the Yenissei, or Ulu-kem river, are spoken of in Chinese chronicles of the 5th century, where it would appear, from a casual allusion to Kirghiz slaves among the Tukiu, in the narrative of Zemarchus's mission to Disobul, they were at that time a vanquished nationality. By the Chinese these Kirghiz are traced back two centuries B.C. These Kirghiz, anciently called Hakas, were overcome by the Tu-kiu or Turks, a race quite distinct from the Hakas, who are supposed to be an Aryan people. Their language is now Turk, and very few traces of their origin have as yet been discovered; but it is not impossible that philological inquiries may yet lead to a discovery of many roots in the languages of the Finns and other tribes of that family of the lost language, the Kirghiz or ancient Hakas.

Language is often a deceptive guide to the determination of primitive stock. Yet it cannot be but that a once numerous and powerful people, at one time speaking a language of their own, have left in those that have superseded it evidences of an earlier form of speech. In the language of the Tongouts in Ordos there are sounds exactly similar to those uttered by the Finns, Laplanders, Savoyards, &c., quite distinct from those in the Turk tongue, albeit these last-named people are considered the Turk race. The author considers that a study of the symbols which are in common use in the far East in place of written characters would probably afford some assistance on the spot to the philological student and serve to throw some light upon the past. Joubert, Abel Remusat, Castrea, and others may be referred to on this subject; and there are said to be caverns in the Sayan mountain-passes where some ancient people deposited their records and relics, which have never been found or even searched for from the Russian side of the country. It is to be remembered that the so-called Kirghiz of the Steppes of North-western Asia have no affinities whatever with the Kirghiz here alluded to. These, now nearly all Russian subjects, do not know the name, and are really Kaisaks (Cossacks), roaming houseless waifs, and they are Turks. The Kirghiz proper are now few in number, and are fast dying out, succumbing to the Caucasians, probably the descendants of this very ancient people.

On the Localities from whence the Gold and Tin of the Ancients were derived.
By CHARLES P. GROOM NAPIER, *F.G.S.*, *M.A.I.*

The author said tin was known from historic evidence at least 1500 years B.C. He quoted Strabo with reference to the Phœnicians carrying on traffic for tin from Gades and Bochart, who deduced the term Britain from *Barab anac*, the land or field of tin. From the Phœnician inscriptions recently published in the journals of the London Anthropological Societies and Institute, as having been found in Brazil and Sumatra, he thought there was an early Phœnician intercourse with these countries, and that metals might have been derived from them. Bochart thought Ophir might be in Peru. The author thought Ophir was a general name for a gold-producing country. He reviewed the various theories with reference to the location of Ophir, and mentioned the leading localities where the gold of antiquity was said by ancient authors to have been procured.

A new Paragraph in Early English History.
By DR. T. NICHOLAS, *M.A.*, *F.G.S.*

The author brought forward evidence, not before presented, to the effect that the letter to Aëtius the Roman Consul, ascribed by Gildas to the Britons of Britain, and beginning, "The groans of the Britons," meant in reality a message to the same effect sent to the same consul and in the same year by the Armoricans, who were even at that early date (A.D. 447) often called Britanni, and their country Britannia (Bretagne). He quoted, in proof of his position, more especially from the life of St. Germanus by Constantius, found in the 'Acta Sanctorum,' establishing from this contemporary document the reality of such a message to Aetius from the Armoricans in the year of his third Consulship (A.D. 447), the date of the pretended "letter" given by Gildas. The coincidence was so striking as infallibly to suggest a blunder or a fraud on the part of Gildas, who was writing more than a century after the events, and, according to his own confession, without the aid of any British documents to supply him with facts, but from foreign hearsay and obscure tradition. Whether Gildas was the victim of imposture, or himself played the impostor, and applied to his countrymen the Britons what in reality belonged to the Britanni of Armorica, he is in either case equally unworthy of credence as an authority in early English history.

The Archæological Discoveries in Kent's Cavern, Torquay.
By W. PENGELLY, *F.R.S.*

Note on a recent Notice of Brixham Cavern. *By* W. PENGELLY, *F.R.S.*

On the Works, Manners, and Customs of the Early Inhabitants of the Mendips.
By J. S. PHENÉ, *LL.D.*, *F.S.A.*

In this paper the parallel evidence of various celebrated anthropologists, shown in their discoveries, and the arguments deduced from such discoveries by men of the highest scientific acquirements, were brought to bear upon the occupants of caverns in the west of Europe, from North Britain to Gibraltar, for the purpose of showing a similarity of race in the people occupying the sea-board of nearly the whole of that part of Europe bounded by the Atlantic Ocean. The discoveries by the author not only agreed with the authorities, but showed reasonable ground for supposing that the race of cave occupants known as dolichocephali inhabited as far north as some of the extreme portions of North Britain. And as from a subsequent joint occupancy it was apparent that an invading force in Britain, probably the Cymry, had possessed themselves of the abodes and dwellings of these people, it was probable that the Cymry had occupied territory a good deal further north than was shown by Mr. Skene and other writers on that subject. It would seem, moreover, as a result, that the occupants of the Mendip Hills would originally have been of that race. This being so, the manner and customs of the early inhabitants of the Mendip Hills would approximate to those of the dolichocephalic occupants of Iberia and other western countries. In all such districts were found dolmens and chambered tombs, which appeared to have succeeded as places of interment, if not of residence (or, as the author considered, of both), to the natural caverns occupied by the earlier generations of this people. The interments, even when in connexion with those of the brachycephali, a more powerful and invading race, agreed in manner and accompaniments, including coarse pottery, bones of animals, and neolithic implements. But a prominent feature, hitherto unnoticed, to which the author drew attention, was the construction or arrangement of works sepulchral and otherwise in forms and devices simulating animal outlines; those on the Mendips at Blackdown, Priddy, Beacon Batch, and other places, as well as those at Beacon hill near Maesbury, consist in each case of a series of mounds arranged in studied positions representing very beautiful alternating curves, precisely analogous to the positions that would be assumed by vast serpents of similar dimensions. The vast, stupendous, and terrible appeared the predominant characteristic of such devices; and it was noticeable that in all cases of such constructions, and, so far as he had been able to investigate personally, in all places of such cave occupancy also, the artificial emblems followed on some one or other natural simulation, which had either suggested the idea directly, or led to its adoption in a somewhat varied form. That the simulations of animal forms which were to be found upon the Mendip Hills, as well as elsewhere along the Atlantic districts, were constructed to represent deities, he thought there could be no doubt; and as such simulations appeared to be the result of natural suggestion, he assumed that such natural simulations would have been among the previous objects of worship of the people.

On the Ethnography of the Cimbri. By the Rev. Canon Rawlinson, *B.D.*

Note on the Animal Remains found in Cissbury Camp.

By Professor Rolleston, *F.R.S.*

On the Applicability of Historical Evidence to Ethnographical Inquiries.

By Professor Rolleston, *F.R.S.*

On the Physiognomy of the Ear. By Dr. Simms.

On the Origin of the Maori Races in New Zealand.

By W. S. W. Vaux, *M.A., F.R.S.*

The author considered this question under three heads:—1. Native Tradition; 2. Ethnology; 3. Language.

In the first, he pointed out that there was no reasonable grounds for doubting the native traditions, as these had been found uniformly the same in all parts of the three islands, and, as in other matters, the people had proved themselves to be thoroughly trustworthy.

In the second, he showed that overwhelming evidence demonstrated that the New-Zealanders were one race, the few exceptions noticeable not being of any real moment.

In the third, he proved by a careful examination of the chief Polynesian dialects, the Maori, the Tonga, the Hawaii (Sandwich), the Tahiti (Otaheite), and the Samoan (Navigator's Islands), that all these peoples must once have had a common origin, the difference between the existing dialects being hardly as much as between that of Yorkshire and Somersetshire at the present day, and by no means as great as those between the popular dialects of Venice and Naples. The author had no doubt that they all came at some remote period from Central Asia—in other words, were Turanians; but the route they took, he thought, could not now be traced with any certainty.

On the Predatory Races of Asia and Europe; a Chapter in Morals. *By* C. Staniland Wake, *V.-P.L.A.S.*

Notwithstanding the practice by peoples such as the Afghans, the Bedouins, the Slavonians of Southern Europe, and the ancient peoples of North-western Europe, classed together by the author as "predatory," of the right of blood-revenge, such peoples are not without certain important moral characteristics. Among all of them that right has come to be usually given up in return for a compensation, pecuniary or otherwise, fixed by arbitration or by the person [injured or his relations. Moreover, although towards strangers their conduct is governed by no sense of moral obligation, yet as between themselves the ordinary rules of the moral law required for the internal peace and prosperity of the state are recognized. In general conduct the predatory peoples show a great superiority over less cultured races. The practice of hospitality has become a virtue and a sacred tie of friendship. Marriage has ceased to be a matter of mere bargain and sale, and woman has become the wife instead of the slave of her husband. The whole character of the predatory peoples has, indeed, acquired a higher moral tone. Partly owing to the influence acquired by woman and her power of moulding the character of her children, but chiefly owing to the recognition of the true position of the father as the head of the family, in substitution for the primitive notion of relationship to the clan through the mother, the feeling of "manliness" is developed to a great degree. This was noticeable in the character of the ancient Germans and Scandinavians no less than in that of the modern predatory peoples of Asia. With them "manliness" springs from an intense self-consciousness, and it shows its influence in the dignity, self-control, and magnanimity for which those peoples are distinguished. Those characteristics are accompanied by a sense of personal honour which is essential to a true idea of moral obligation; although moral strength rather than moral goodness is the special attribute of the predatory peoples. We see the same thing among the ancient Romans, who possessed the quality of "manliness" in a high degree. This quality was to them the sum of all morality, to which, indeed, they gave the name of "virtue," meaning *strength*, as applied to conduct. The "virtue" of the Romans and of the ancient peoples of Europe was thus originally the same quality, and it possessed with each the possibility of acquiring a true ethical sense.

The Cycle of Development. *By* Hodder M. Westropp.

The object of the author is to trace and bring into prominence the cycle of development, an invariable law which, in his opinion, presides over all that has growth and progress, in man and in nature. All progress and growth is in successive stages, which form a cycle, the stages proceeding in an ascending scale and in a descending scale—those in the ascending scale being rise, progress, maturity; in the descending, decline, decay, and extinction.

GEOGRAPHY.

Address by Lieut.-General R. STRACHEY, *R.E., C.S.I., F.R.S., President of the Section.*

IN accordance with the practice followed for some years past by the Presidents of the Sections of the British Association, I propose, before proceeding with our ordinary business, to offer for your consideration some observations relative to the branch of knowledge with which this Section is more specially concerned.

My predecessors in this Chair have, in their opening addresses, viewed Geography in many various lights. Some have drawn attention to recent geographical discoveries of interest, or to the gradual progress of geographical knowledge over the earth generally, or in particular regions. Others have spoken of the value of geographical knowledge in the ordinary affairs of men, or in some of the special branches of those affairs, and of the means of extending such knowledge. Other addresses again have dwelt on the practical influence produced by the geographical features and conditions of the various parts of the earth on the past history and present state of the several sections of the human race, the formation of kingdoms, the growth of industry and commerce, and the spread of civilization.

The judicious character of that part of our organization which leads to yearly changes among those who preside over our meetings, and does not attempt authoritatively to prescribe the direction of our discussions, will no doubt be generally recognized. It has the obvious advantage, amongst others, of ensuring that none of the multifarious claims to attention of the several branches of science shall be made unduly prominent, and of giving opportunity for viewing the subjects which from time to time come before the Association in fresh aspects by various minds.

Following, then, a somewhat different path from those who have gone before me in treating of Geography, I propose to speak of the physical causes which have impressed on our planet the present outlines and forms of its surface, have brought about its present conditions of climate, and have led to the development and distribution of the living beings found upon it.

In selecting this subject for my opening remarks, I have been not a little influenced by a consideration of the present state of geographical knowledge, and of the probable future of geographical investigation. It is plain that the field for mere topographical exploration is already greatly limited, and that it is continually becoming more restricted. Although no doubt much remains to be done in obtaining detailed maps of large tracts of the earth's surface, yet there is but comparatively a very small area with the essential features of which we are not now fairly well acquainted. Day by day our maps become more complete, and with our greatly improved means of communication the knowledge of distant countries is constantly enlarged and more widely diffused. Somewhat in the same proportion the demands for more exact information become more pressing. The necessary consequence is an increased tendency to give to geographical investigations a more strictly scientific direction. In proof of this I may instance the fact that the two British naval expeditions now being carried on, that of the Challenger and that of the Arctic seas, have been organized almost entirely for general scientific research, and comparatively little for topographical discovery. Narratives of travels, which not many years ago might have been accepted as valuable contributions to our then less perfect knowledge, would now perhaps be regarded as superficial and insufficient. In short the standard of knowledge of travellers and writers on Geography must be raised to meet the increased requirements of the time.

Other influences are at work tending to the same result. The great advance made in all branches of natural science limits more and more closely the facilities for original research, and draws the observer of nature into more and more special studies, while it renders the acquisition by any individual of the highest standard of knowledge in more than one or two special subjects comparatively difficult and rare. At the same time the mutual interdependence of all natural phenomena daily becomes more apparent; and it is of ever-increasing importance that there shall be some among the cultivators of natural knowledge who specially direct their attention to the general relations existing among all the forces and phenomena of nature. In some important branches of such subjects, it is only through study of the local physical conditions of various parts of the earth's surface and the complicated phenomena to which they give rise, that sound conclusions can be established; and this study constitutes Physical or Scientific Geography. It is very necessary to bear in mind that a large portion of the phenomena dealt with by the sciences of observation relates to the earth as a whole in contradistinction to the substances of which it is formed, and can only be correctly appreciated in connexion with the terrestrial or geographical conditions of the place where they occur. On the one hand therefore, while the proper prosecution of the study of Physical Geography requires a sound knowledge of the researches and conclusions of students in the special branches of science, on the other success is not attainable in the special branches without suitable apprehension of geographical facts. For these reasons it appears to me that the general progress of science will involve the study of Geography in a more scientific spirit, and with a clearer conception of its true function, which is that of obtaining accurate notions of the manner in which the forces of nature have brought about the varied conditions characterizing the surface of the planet which we inhabit.

In its broadest sense Science is organized knowledge, and its methods consist of the observation and classification of the phenomena of which we become conscious through our senses, and the investigation of the causes of which these are the effects. The first step in Geography, as in all other sciences, is the observation and description of the phenomena with which it is concerned; the next is to classify and compare this empirical collection of facts, and to investigate their antecedent causes. It is in the first branch of the study that most progress has been made, and to it indeed the notion of Geography is still popularly limited. The other branch is commonly spoken of as Physical Geography, but it is more correctly the science of Geography.

The progress of Geography has thus advanced from first rough ideas of relative distance between neighbouring places, to correct views of the earth's form, precise determinations of position, and accurate delineations of the surface. The first impressions of the differences observed between distant countries were at length corrected by the perception of similarities no less real. The characteristics of the great regions of polar cold and equatorial heat, of the sea and land, of the mountains and plains, were appreciated; and the local variations of season and climate, of wind and rain, were more or less fully ascertained. Later, the distribution of plants and animals, their occurrence in groups of peculiar structure in various regions, and the circumstances under which such groups vary from place to place gave rise to fresh conceptions. Along with these facts were observed the peculiarities of the races of men—their physical form, languages, customs, and history—exhibiting on the one hand striking differences in different countries, but on the other often connected by a strong stamp of similarity over large areas.

By the gradual accumulation and classification of such knowledge the scientific conception of geographical unity and continuity was at length formed, and the conclusion established that while each different part of the earth's surface has its special characteristics, all animate and inanimate nature constitutes one general system, and that the particular features of each region are due to the operation of universal laws acting under varying local conditions. It is upon such a conception that is now brought to bear the doctrine, very generally accepted by the naturalists of our own country, that each successive phase of the earth's history, for an indefinite period of time, has been derived from that which preceded it, under the operation of the forces of nature as we now find them; and that, so far as observation justifies the adoption of any conclusions on such subjects, no change has ever taken place in those forces or in the properties of matter. This doctrine is commonly spoken of as the doctrine of evolution, and it is to its application to Geography that I wish to direct your attention.

I desire here to remark that in what I am about to say, I altogether leave on one side all questions relating to the origin of matter, and of the so-called forces of nature which give rise to the properties of matter. In the present state of knowledge such subjects are, I conceive, beyond the legitimate field of physical science, which is limited to discussions directly arising on facts within the reach of observation, or on reasonings based on such facts. It is a necessary condition of the progress of knowledge that the line between what properly is or is not within the reach of human intelligence is ill defined, and that opinions will vary as to where it should be drawn; for it is the avowed and successful aim of science to keep this line constantly shifting by pushing it forward; many of the efforts made to do this are no doubt founded in error, but all are deserving of respect that are undertaken honestly.

The conception of evolution is essentially that of a passage to the state of things which observation shows us to exist now, from some preceding state of things. Applied to Geography, that is to say to the present condition of the earth as a whole, it leads up to the conclusion that the existing outlines of sea and land have been caused by modifications of pre-existing oceans and continents, brought about by the operation of forces which are still in action, and which have acted from the most remote past of which we can conceive; that all the successive forms of the surface,—the depressions occupied by the waters, and the elevations constituting mountain-chains,—are due to these same forces; that these have been set up, first, by the secular loss of heat which accompanied the original cooling of the globe, and second, by the annual or daily gain and loss of heat received from the sun acting on the matter of which the earth and its atmosphere are composed; that all variations of climate are dependent on differences in the condition of the surface; that the distribution of life on the earth, and the vast varieties of its forms, are consequences of contemporaneous or antecedent changes of the forms of the surface and climate; and thus that our planet as we now find it is the result of modifications gradually brought about in its successive stages, by the necessary action of the matter out of which it has been formed, under the influence of the matter which is external to it.

I shall state briefly the grounds on which these conclusions are based.

So far as concerns the inorganic fabric of the earth, that view of its past history which is based on the principle of the persistence of all the forces of nature, may be said to be now universally adopted. This teaches that the almost infinite variety of natural phenomena arises from new combinations of old forms of matter, under the action of new combinations of old forms of force. Its recognition has, however, been comparatively recent, and is in a great measure due to the teachings of that eminent geologist, the late Sir Charles Lyell, whom we have lost during the past year.

When we look back by the help of geological science to the more remote past, through the epochs immediately preceding our own, we find evidence of marine animals—which lived, were reproduced, and died,—posssessed of organs proving that they were under the influence of the heat and light of the sun; of seas whose waves rose before the winds, breaking down cliffs, and forming beaches of boulders and pebbles; of tides and currents spreading out banks of sand and mud, on which are left the impress of the ripple of the water, of drops of rain, and of the track of animals; and all these appearances are precisely similar to those we observe at the present day as the result of forces which we see actually in operation. Every successive stage, as we recede in the past history of the earth, teaches the same lesson. The forces which are now at work, whether in degrading the surface by the action of seas, rivers, or frosts, and in transporting its fragments into the sea, or in reconstituting the land by raising beds laid out in the depth of the ocean, are traced by similar effects as having continued in action from the earliest times.

Thus pushing back our inquiries we at last reach the point where the apparent cessation of terrestrial conditions such as now exist requires us to consider the relation in which our planet stands to other bodies in celestial space; and vast though the gulf be that separates us from these, science has been able to bridge it. By means of spectroscopic analysis it has been established that the constituent elements of the sun and other heavenly bodies are substantially the same as those of the earth. The examination of the meteorites which have fallen on the earth from the interplanetary spaces shows that they also contain nothing foreign to the constituents of the earth. The inference seems legitimate, corroborated as it is by the manifest physical connexion between the sun and the planetary bodies circulating around it, that the whole solar system is formed of the same descriptions of matter, and subject to the same general physical laws. These conclusions further support the supposition that the earth and other planets have been formed by the aggregation of matter once diffused in space around the sun; that the first consequence of this aggregation was to develop intense heat in the consolidating masses; that the heat thus generated in the terrestrial sphere was subsequently lost by radiation; and that the surface cooled and became a solid crust, leaving a central nucleus of much higher temperature within. The earth's surface appears now to have reached a temperature which is virtually fixed, and on which the gain of heat from the sun is, on the whole, just compensated by the loss by radiation into surrounding space.

Such a conception of the earliest stage of the earth's existence is commonly accepted, as in accordance with observed facts. It leads to the conclusion that the hollows on the surface of the globe occupied by the ocean, and the great areas of dry land, were original irregularities of form caused by unequal contraction; and that the mountains were corrugations, often accompanied by ruptures, caused by the strains developed in the external crust by the force of central attraction exerted during cooling, and were not due to forces directly acting upwards generated in the interior by gases or otherwise. It has recently been very ably argued by Mr. Mallet that the phenomena of volcanic heat are likewise consequences of extreme pressures in the external crust, set up in a similar manner, and are not derived from the central heated nucleus.

There may be some difficulty in conceiving how forces can have been thus developed sufficient to have produced the gigantic changes which have occurred in the distribution of land and water over immense areas, and in the elevation of the bottoms of former seas so that they now form the summits of the highest mountains, and to have effected such changes within the very latest geological epoch. These difficulties in great measure arise from not employing correct standards of space and time in relation to the phenomena. Vast though the greatest heights of our mountains and depths of our seas may be, and enormous though the masses which have been put into motion, when viewed according to a human standard, they are insignificant in relation to the globe as a whole. Such heights and depths (about 6 miles) on a sphere of 10 feet in diameter would be represented on a true scale by elevations and depressions of less than the tenth part of an inch, and the average elevation of the whole of the dry land (about 1000 feet) above the mean level of the surface would hardly amount to the thickness of an ordinary sheet of paper. The forces developed by the changes of the temperature of the earth as a whole must be proportionate to its dimensions; and the results of their action on the surface in causing elevations, contortions, or disruptions of the strata, cannot be commensurable with those produced by forces having the intensities, or by strains in bodies of the dimensions, with which our ordinary experience is conversant.

The difficulty in respect to the vast extent of past time is perhaps less great, the conception being one with which most persons are now more or less familiar. But I would remind you, that great though the changes in human affairs have been since the most remote epochs of which we have records in monuments or history, there is nothing to indicate that within this period has occurred any appreciable modification of the main outlines of land and sea, or of the conditions of climate, or of the general characters of living creatures; and that the distance that separates us from those days is as nothing when compared to the remoteness of past geological ages. No useful approach has yet been made to a numerical estimate of the duration even of that portion of geological time which is nearest to us; and we can say little more than that the earth's past history extends over hundreds of thousands or millions of years.

The solid nucleus of the earth with its atmosphere, as we now find them, may thus be regarded as exhibiting the residual phenomena which have resulted on its attaining a condition of practical equilibrium, the more active process of aggregation having ceased, and the combination of its elements into the various solid, liquid, or gaseous matters found on or near the surface having been completed. During its passage to its present state many wonderful changes must have taken place, including the condensation of the ocean, which must have long continued in a state of ebullition, or bordering on it, surrounded by an atmosphere densely charged with watery vapour. Apart from the movements in its solid crust caused by the general cooling and contraction of the earth, the higher temperature due to its earlier condition hardly enters directly into any of the considerations that arise in connexion with its present climate, or with the changes during past time which are of most interest to us; for the conditions of climate and temperature at present, as well as in the period during which the existence of life is indicated by the presence of fossil remains, and which have affected the production and distribution of organized beings, are dependent on other causes, to a consideration of which I now proceed.

The natural phenomena relating to the atmosphere are often extremely complicated and difficult of explanation; and meteorology is the least advanced of the branches of physical science. But sufficient is known to indicate, without possible doubt, that the primary causes of the great series of phenomena, included under the general term climate, are the action and reaction of the mechanical and chemical forces set in operation by the sun's heat, varied from time to time and from place to place, by the influence of the position of the earth in its orbit, of its revolution on its axis, of geographical position, elevation above the sea-level, and condition of the surface, and by the great mobility of the atmosphere and the ocean.

The intimate connexion between climate and local geographical conditions is everywhere apparent; nothing is more striking than the great differences between neighbouring places where the effective local conditions are not alike, which often far surpass the contrasts attending the widest separation possible on the globe. Three or four miles of vertical height produce effects almost equal to those of transfer from the equator to the poles. The distribution of the great seas and continents give rise to periodical winds—the trades and monsoons—which maintain their general characteristics over wide areas, but present almost infinite local modifications whether of season, direction, or force. The direction of the coasts and their greater or less continuity greatly influence the flow of the currents of the ocean; and these, with the periodical winds, tend on the one hand to equalize the temperature of the whole surface of the earth, and on the other to cause surprising variations within a limited area. Ranges of mountains, and their position in relation to the periodical or rain-bearing winds, are of primary importance in controlling the movements of the lower strata of the atmosphere, in which, owing to the laws of elastic gases, the great mass of the air and watery vapour are concentrated. By their presence they may either constitute a barrier across which no rain can pass, or determine the fall of torrents of rain around them. Their absence or their unfavourable position, by removing the causes of condensation, may lead to the neighbouring tracts becoming rainless deserts.

The difficulties that arise in accounting for the phenomena of climate on the earth as it now is, are naturally increased when the attempt is made to explain what is shown by geological evidence to have happened in past ages. The disposition has not been wanting to get over these last difficulties by invoking supposed changes in the sources of terrestrial heat, or in the conditions under which heat has been received by the earth, for which there is no justification in fact, in a manner similar to that in which violent departures from the observed course of nature have been assumed to account for some of the analogous mechanical difficulties.

Among the most perplexing of such climatal problems are those involved in the former extension of glacial action of various sorts over areas which could hardly have been subject to it under existing terrestrial and solar conditions; and in the discovery, conversely, of indications of far higher temperatures at certain places than seems compatible with their high latitudes; and in the alternations of such extreme conditions. The true solution of these questions has apparently been found in the recognition of the disturbing effects of the varying eccentricity of the earth's orbit, which, though inappreciable in the comparatively few years to which the affairs of men are limited, become of great importance in the vastly increased period brought into consideration when dealing with the history of the earth. The changes of eccentricity of the orbit are not of a nature to cause appreciable differences in the mean temperature either of the earth generally or of the two hemispheres; but they may, when combined with changes of the direction of the earth's axis caused by the precession of the equinoxes and nutation, lead to exaggeration of the extremes of heat and cold, or to their diminution; and this would appear to supply the means of explaining the observed facts, though doubtless the detailed application of the conception will long continue to give rise to discussions. Mr. Croll, in his book entitled 'Climate and Time,' has recently brought together with much research all that can now be said on this subject; and the general correctness of that part of his conclusions which refers to the periodical occurrence of epochs of greatly increased winter cold and summer heat in one hemisphere, combined with a more equable climate in the other, appears to me to be fully established.

These are the considerations which are held to prove that the inorganic structure of the globe through all its successive stages—the earth beneath our feet, with its varied surface of land and sea, mountain and plain, and with its atmosphere which distributes heat and moisture over that surface,—has been evolved as the necessary result of the original aggregation of matter at some extremely remote period, and of the subsequent modification of that matter in condition and form under the exclusive operation of invariable physical forces.

From these investigations we carry on the inquiry to the living creatures found upon the earth; what are their relations one to another, and what to the inorganic world with which they are associated?

This inquiry first directed to the present time, and thence carried backwards as far as possible into the past, proves that there is one general system of life, vegetable and animal, which is coextensive with the earth as it now is, and as it has been in all the successive stages of which we obtain a knowledge by geological research. The phenomena of life, as thus ascertained, are included in the organization of living creatures, and their distribution in time and place. The common bond that subsists between all vegetables and animals is testified by the identity of the ultimate elements of which they are composed. These elements are carbon, oxygen, hydrogen, and nitrogen, with a few others in comparatively small quantities; the whole of the materials of all living things being found among those that compose the inorganic portion of the earth.

The close relation existing between the least specialized animals and plants, and between these and organic matter not having life, and even with inorganic matter, is indicated by the difficulty that arises in determining the nature of the distinctions between them. Among the more highly developed members of the two great branches of living creatures, the well-known similarities of structure observed in the various groups indicate a connexion between proximate forms which was long seen to be akin to that derived through descent from a common ancestor by ordinary generation.

The facts of distribution show that certain forms are associated in certain areas, and that as we pass from one such area to another the forms of life change also. The general assemblages of living creatures in neighbouring countries easily accessible to one another, and having similar climates, resemble one another; and much in the same way, as the distance between areas increases, or their mutual accessibility diminishes, or the conditions of climate differ, the likeness of the forms within them becomes continually less apparent. The plants and animals existing at any time in any locality tend constantly to diffuse themselves around that local centre, this tendency being controlled by the conditions of climate, &c. of the surrounding area, so that under certain unfavourable conditions diffusion ceases.

The possibilities of life are further seen to be everywhere directly influenced by all external conditions, such as those of climate, including temperature, humidity, and wind; of the length of the seasons and days and nights; of the character of the surface whether it be land or water, and whether it be covered by vegetation or otherwise; of the nature of the soil; of the presence of other living creatures, and many more. The abundance of forms of life in different areas (as distinguished from number of individuals) is also found to vary greatly, and to be related to the accessibility of such areas to immigration from without; to the existence, within or near the areas, of localities offering considerable variations of the conditions that chiefly affect life; and to the local climate and conditions being compatible with such immigration.

For the explanation of these and other phenomena of organization and distribution, the only direct evidence that observation can supply is that derived from the mode of propagation of creatures now living; and no other mode is known than that which takes place by ordinary generation, through descent from parent to offspring.

It was left for the genius of Darwin to point out how the course of nature as it now acts in the reproduction of living creatures, is sufficient for the interpretation of what had previously been incomprehensible in these matters. He showed how propagation by descent operates subject to the occurrence of certain small variations in the offspring, and that the preservation of some of these varieties to the exclusion of others follows as a necessary consequence when the external conditions are more suitable to the preserved forms than to those lost. The operation of these causes he called Natural Selection. Prolonged over a great extent of time it supplies the long-sought key to the complex system of forms either now living on the earth, or the remains of which are found in the fossil state, and explains the relations among them, and the manner in which their distribution has taken place in time and space.

Thus we are brought to the conclusion that the directing forces which have been efficient in developing the existing forms of life from those which went before them, are those same successive external conditions, including both the forms of land and sea and the character of the climate, which have already been shown to arise from the gradual modification of the material fabric of the globe as it slowly attained to its present state. In each succeeding epoch, and in each separate locality, the forms preserved and handed on to the future were determined by the general conditions of surface at the time and place; and the aggregate of successive sets of conditions over the whole earth's surface has determined the entire series of forms which have existed in the past and have survived till now.

As we recede from the present into the past, it necessarily follows, as a consequence of the ultimate failure of all evidence as to the conditions of the past, that positive testimony of the conformity of the facts with the principle of evolution gradually diminishes, and at length ceases. In the same way positive evidence of the continuity of action of all the physical forces of nature eventually fails. But inasmuch as the evidence, so far as it can be procured, supports the belief in this continuity of action, and as we have no experience of the contrary being possible, the only justifiable conclusion is, that the production of life must have been going on as we now know it, without any intermission, from the time of its first appearance on the earth.

These considerations manifestly afford no sort of clue to the origin of life. They only serve to take us back to a very remote epoch, when the living creatures differed greatly in detail from those of the present time, but had such resemblances to them as to justify the conclusion that the essence of life then was the same as now; and through that epoch into an unknown anterior period, during which the possibility of life, as we understand it, began, and from which has emerged, in a way that we cannot comprehend, matter with its properties, bound together by what we call the elementary physical forces. There seems to be no foundation in any observed fact for suggesting that the wonderful property which we call life appertains to the combinations of elementary substances in association with which it is exclusively found, otherwise than as all other properties appertain to the particular forms or combinations of matter with which they are associated. It is no more possible to say how originated or operates the tendency of some sorts of matter to take the form of vapours, or fluids, or solid bodies, in all their various shapes, or for the various sorts of matter to attract one another or combine, than it is to explain the origin in certain forms of matter of the property we call life, or the mode of its action. For the present, at least, we must be content to accept such facts as the foundation of positive knowledge, and from them to rise to the apprehension of the means by which nature has reached its present state, and is advancing into an unknown future.

These conceptions of the relations of animal and vegetable forms to the earth in its successive stages lead to views of the significance of type (*i. e.* the general system of structure running through various groups of organized beings) very different from those under which it was held to be an indication of some occult power directing the successive appearance of living creatures on the earth. In the light of evolution, type is nothing more than the direction given to the actual development of life by the surface-conditions of the earth, which have supplied the forces that controlled the course of the successive generations leading from the past to the present. There is no indication of any inherent or pre-arranged disposition towards the development of life in any particular direction. It would rather appear that the actual face of nature is the result of a succession of apparently trivial incidents, which by some very slight alteration of local circumstances might often, it would seem, have been turned in a different direction. Some otherwise unimportant difference in the constitution or sequence of the substrata at any locality might have determined the elevation of mountains where a hollow filled by the sea was actually formed, and thereby the whole of the climatal and other conditions of a large area would have been changed, and an entirely different impulse given to the development of life locally, which might have impressed a new character on the whole face of nature.

But further, all that we see or know to have existed upon the earth has been controlled to its most minute details by the original constitution of the matter which was drawn together to form our planet. The actual character of all inorganic substances, as of all living creatures, is only consistent with the actual constitution and proportions of the various substances of which the earth is composed. Other proportions than the actual ones in the constituents of the atmosphere would have required an entirely different organization in all air-breathing animals, and probably in all plants. With any considerable difference in the quantity of water either in the sea or distributed as vapour, vast changes in the constitution of living creatures must have been involved. Without oxygen, hydrogen, nitrogen, or carbon, what we term life would have been impossible. But such speculations need not be extended.

The substances of which the earth is now composed are identical with those of which it has always been made up; so far as is known it has lost nothing and has gained nothing, except what has been added in extremely minute quantities by the fall of meteorites. All that is or ever has been upon the earth is part of the earth, has sprung from the earth, is sustained by the earth, and returns to the earth; taking back thither what it withdrew, making good the materials on which life depends, without which it would cease, and which are destined again to enter into new forms, and contribute to the ever onward flow of the great current of existence.

The progress of knowledge has removed all doubt as to the relation in which the human race stands to this great stream of life. It is now established that man existed on the earth at a period vastly anterior to any of which we have records in history or otherwise. He was the contemporary of many extinct mammalia at a time when the outlines of land and sea, and the conditions of climate over large parts of the earth, were wholly different from what they now are, and our race has been advancing towards its present condition during a series of ages for the extent of which ordinary conceptions of time afford no suitable measure. These facts have, in recent years, given a different direction to opinion as to the manner in which the great groups of mankind have become distributed over the areas where they are now found; and difficulties once considered insuperable become soluble when regarded in connexion with those great alterations of the outlines of land and sea which are shown to have been going on up to the very latest geological periods. The ancient monuments of Egypt, which take us back perhaps 7000 years from the present time, indicate that when they were erected the neighbouring countries were in a condition of civilization not very greatly different from that which existed when they fell under the dominion of the Romans or Mahometans hardly 1500 years ago; and the progress of the population towards that condition can hardly be accounted for otherwise than by prolonged gradual transformations going back to times so far distant as to require a geological rather than an historical standard of reckoning.

Man, in short, takes his place with the rest of the animate world, in the advancing front of which he occupies so conspicuous a position. Yet for this position he is indebted not to any exclusive powers of his own, but to the wonderful compelling forces of nature which have lifted him entirely without his knowledge, and almost without his participation, so far above the animals of whom he is still one, though the only one able to see or consider what he is.

For the social habits essential to his progress, which he possessed even in his most primitive state, man is without question dependent on his ancestors, as he is for his form and other physical peculiarities. In his advance to civilization he was insensibly forced, by the pressure of external circumstances, through the more savage condition, in which his life was that of the hunter, first to pastoral and then to agricultural occupations. The requirements of a population gradually increasing in numbers could only be met by a supply of food more regular and more abundant than could be provided by the chase. But the possibility of the change from the hunter to the shepherd or herdsman rested on the antecedent existence of animals suited to supply man with food, having gregarious habits, and fitted for domestication, such as sheep, goats, and horned cattle; for their support the social grasses were a necessary preliminary, and for the growth of these in sufficient abundance land naturally suitable for pasture was required. A further evasion of man's growing difficulty in obtaining sufficient food was secured by aid of the cereal grasses, which supplied the means by which agriculture, the outcome of pastoral life, became the chief occupation of more civilized generations. Lastly, when these increased facilities for providing food were in turn overtaken by the growth of the population, new power to cope with the recurring difficulty was gained through the cultivation of mechanical arts and of thought, for which the needful leisure was for the first time obtained when the earliest steps of civilization had removed the necessity for unremitting search after the means of supporting existence. Then was broken down the chief barrier in the way of progress, and man was carried forward to the condition in which he now is.

It is impossible not to recognize that the growth of civilization, by aid of its instruments, pastoral and agricultural industry, was the result of the unconscious adoption of defences supplied by what was exterior to man, rather than of any truly intelligent steps taken with forethought to attain it; and in these respects man, in his struggle for existence, has not differed from the humbler animals or from plants. Neither can the marvellous ultimate growth of his knowledge, and his acquisition of the power of applying to his use all that lies without him, be viewed as differing in any thing but form or degree from the earlier steps in his advance. The needful protection against the foes of his constantly increasing race—the legions of hunger and disease, infinite in number, ever changing their mode of attack or springing up in new shapes—could only be attained by some fresh adaptation of his organization to his wants, and this has taken the form of that development of intellect which has placed all other creatures at his feet and all the powers of nature in his hand.

The picture that I have thus attempted to draw presents to us our earth carrying with it, or receiving from the sun or other external bodies, as it travels through celestial space, all the materials and all the forces by help of which are fashioned whatever we see upon it. We may liken it to a great complex living organism, having an inert substratum of inorganic matter on which are formed many separate organized centres of life, but all bound up together by a common law of existence, each individual part depending on those around it, and on the past condition of the whole. Science is the study of the relations of the several parts of this organism one to another, and of the parts to the whole. It is the task of the geographer to bring together from all places on the earth's surface the materials from which shall be deduced the scientific conception of nature. Geography supplies the rough blocks wherewith to build up that grand structure towards the completion of which science is striving. The traveller, who is the journeyman of science, collects from all quarters of the earth observations of fact, to be submitted to the research of the student, and to provide the necessary means of verifying the inductions obtained by study or the hypotheses suggested by it. If, therefore, travellers are to fulfil the duties put upon them by the division of scientific labour, they must maintain their knowledge of the several branches of science at such a standard as will enable them thoroughly to apprehend what are the present requirements of science, and the classes of fact on which fresh observation must be brought to bear to secure its advance. Nor does this involve any impracticable course of study. Such knowledge as will fit a traveller for usefully participating in the progress of science is now placed within the reach of every one. The lustre of that energy and self-devotion which characterize the better class of explorers will not be dimmed by joining to it an amount of scientific training which will enable them to bring away from distant regions enlarged conceptions of other matters besides mere distance and direction. How great is the value to science of the observations of travellers endowed with a share of scientific instruction is testified by the labours of many living naturalists. In our days this is especially true; and I appeal to all who desire to promote the progress of geographical science as explorers, to prepare themselves for doing so efficiently, while they yet possess the vigour and physical powers that so much conduce to success in such pursuits.

On the Physical Geography of South Africa, and Products and Prospects of the Cape of Good Hope. By J. C. Brown, *LL.D.*

The contour of South Africa has been likened to an inverted dinner-plate, on the rim of which the colonies are situated. It has apparently been upheaved in a mass. Much of it is covered by bushes of no great height; but differences of soil are indicated by other productions. Lignite and coal, copper and gold, rubies and diamonds are found in different localities. Forests appear to have been much more extensive than now. Corn and wine are produced. At present the inhabitants are to a great extent pastoral; but this is apparently a temporary and transitional preparation for agriculture, for which are required moisture, labour, capital, skill, and facilities for the transport of agricultural products at moderate expense. Labour is being drawn to South Africa by diamonds and gold. Capital is being increased by the investment of money obtained for these; railways are rapidly extended; and much water, which might be secured and utilized, at present escapes to the sea.

On the late Inundations in France viewed in connexion with Reboisement and Gazonnement on the Alps, Cevennes, and Pyrenees, employed as a means of extinguishing and preventing the Formation of Torrents. By J. C. Brown, *LL.D.*

In 1793 Fabre showed that torrents were attributable to the destruction of forests on the mountains. In 1841 Sarell showed that torrents appear and disappear as forests were destroyed and reproduced. In 1872 Cezanne showed that this relation between forests and floods can be traced from preadamitic times to the present.

In accordance with these views, in 1860 arrangements were made by the Government for an expenditure of ten million of francs in planting with trees and bushes and herbage mountain ground drained by torrents; and within ten years torrents which were most destructive had become placid perennial streams. The Alpine torrents are occasioned in autumn by storms of rain, and in spring by the melting of snow. The late inundations were occasioned by a storm of rain causing a melting of snow, and the substance of both flowing away simultaneously. Had the basins drained been covered with forests the flood would have been delayed and warning might have been given, and the flood would have been protracted, and it might have occurred without rising above the level of the river-banks.

The *reboisement* of all the *bassin de réception* of mountain-torrents has been begun. Previous to the war a million of francs a year were being spent upon the work. A selection of localities had to be made; the propriety of the selection made has never been questioned, and the magnitude of the disaster which has occurred may be considered to justify the expediting of the work at even a greater expenditure than was incurred during the first decade of the operations.

On South-African Torrential Floods viewed in connexion with the late Inundations in the Valley of the Garonne and its Affluences, and Measures adopted in France to prevent such Floods. By J. C. Brown, *LL.D.*

The aridity of South Africa is extreme; it is attributable primarily to the drainage consequent on upheaval, and secondarily to evaporation, promoted by the destruction of vegetation mainly by fire; and in so far it is typical of many other colonized lands. But withal, as is also the case with many of these, there are frequent occasional floods and very destructive inundations. These are occasioned, like the autumn torrents in the Alps, by storms of rain. The production of torrents by these has in many localities been prevented by planting the basin drained by them with trees and shrubs and herbage. The operation of these in producing their effect has been ascertained. From this it appears to be reasonable that they would be also efficacious in regulating the flow of torrents elsewhere; and the losses of life and property reported as consequences of such inundations, warrant a large expenditure as preventive measures, as is incurred in France, to prevent by such means the occurrence of such inundations as have lately occurred in the valley of the Garonne.

*Bearings of recent Observations on the Doctrine of Oceanic Circulation**. *By* Dr. W. B. Carpenter, *F.R.S.*

On Dacotah, North-west America. By Colonel H. B. Carrington.

Journey towards the Outlet of the Nile from the Lake Albert Nyanza. By Lieutenant Chippindale.

On the North-west African Expedition.
By General Sir Arthur Cotton, *R.E.*

There are now thirteen or fourteen expeditions, either actually penetrating Central Africa or preparing to start, from five or six different countries; all the fruit of Livingstone's leading.

Why should a hundred millions of our fellow men be shut out from intercourse with the civilized races? And how could a young man propose to himself a more worthy enterprise than Mr. M'Kenzie has of bringing Timbuctoo within easy reach of England?

The testimony of several witnesses seems conclusive as to a great area between the Atlas mountains and the Niger being below the level of the sea, and separated from it only by a short space. Its extremity near the sea is about 10 miles wide, and covered with a crust of salt. The tribes of the country surrounding this depression are stated to be very hospitable and tractable. This direct line of communication with Timbuctoo was strongly recommended by Mr. Jackson, a merchant who resided on the coast many years (60 years ago), and his plans were strongly supported by Vasco de Gama and Mr. Willis, formerly Consul at Senegambia.

Such a direct and cheap line of transit would greatly increase the present large traffic which is brought from the Mediterranean, the direct line being not only the shortest but the healthiest and most free from other difficulties.

This is the best land-route incomparably; but the great question is, whether the inland sea cannot be restored. The nature and extent of the bar at the mouth of what is called the Belta, the level and actual area of the depression, the quantity of water flowing into it, &c., are the points now to be ascertained; also how near shelter for shipping is to be found on the coast.

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* *Vide* Proc. Roy. Geogr. Soc. vol. xix. no. vii. (1875).

Another point is the practicability of the Niger for navigation. It is now navigable by steamers for 500 miles, thence to Timbuctoo 1000, and above that may be navigable for 500 more.

A complete line of navigation from the Atlantic by the inland sea, a canal to the Niger, and down the Niger, in all 2300 miles, would open the whole region.

Mr. M'Kenzie proposes to go first to the coast and ascertain what he can without penetrating far, then to return and report to the public, and propose for a thorough exploration of the whole line from the Atlantic to Timbuctoo and round to the Bight of Benin.

There are probably twenty millions of people in North-western Africa, many of whom would be affected by this enterprise.

The probable ultimate effects of an inland sea on the surrounding country and on South Europe is not the question at present; but we need information to justify us in further investigation. If the area is as great as represented, an immense body of water would be required; but while it was filling it would be available so far as the water extended.

The south side of this depression is a fertile and populous country with two large towns, dividing the district into three portions of about 300 miles each; so that there does not appear any great obstacle to the land carriage.

The point proposed to be occupied on the coast is at present without any inhabitants, being south of the kingdom of Morocco, and there appears nothing in the way of our establishing a depot there.

The establishment of English missions and commercial depots on this line would greatly support our operations on the Gold Coast. Both the colonial and foreign offices have expressed an interest in the undertaking.

On the 'Challenger's' Crucial Test of the Wind and Gravitation Theories of Oceanic Circulation[*]. *By* JAMES CROLL, *of H.M. Geol. Survey.*

North Atlantic.—The researches of the 'Challenger' expedition bring to light the striking and important fact that the general surface of the North Atlantic, to be in equilibrium, must stand at a higher level than that of the ocean at the equator. In other words, the surface of the Atlantic is lowest at the equator, and rises with a gentle slope to well nigh the latitude of England—a result which proves the physical impossibility, in so far as the North Atlantic is concerned, of any general interchange of equatorial and polar water due to gravitation.

In order to establish this point a section was taken of the Mid-Atlantic, north and south, across the equator, viz. that section adopted by Dr. Carpenter as the one of all others most favourable to the gravitation theory[†].

On looking at this section the author was forcibly struck that, if it was accurately drawn, the ocean, to be in equilibrium, would require to stand at a higher level in the North Atlantic than at the equator. To determine whether such was the case or not the temperature-soundings indicated in the section were obtained from the Hydrographer of the Admiralty. The following Table (p. 192) gives the soundings in question at three stations—the first (A) at latitude 38° N., the second (B) at latitude 23° N., and the third (C) at the equator.

On computing the extent to which the three columns A, B, and C are each expanded by heat, according to Muncke's Table of the expansion of sea-water for every degree Fahrenheit, it was found that column B, to be in equilibrium with column C (the equatorial column), would require to have its surface standing 2 feet 6 inches above the level of column C, and column A fully 3 feet 6 inches above that column. In short, there must be a gradual rise from the equator to latitude 38° N. of 3½ feet. Professor Hubbard's Table of expansion gives almost the same result. Difference in salinity of the columns produces scarcely any sensible effect.

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[*] Published *in extenso* in the 'Philosophical Magazine' for September 1875.

[†] Proc. Roy. Geog. Soc. vol. xviii. p. 362.

Depth in fathoms.	A. Lat. 37° 54′ N. Long. 41° 44′ W.	B. Lat. 23° 10′ N. Long. 38° 42′ W.	C, Mean of six temperature-soundings near equator.	
	Temperature.	Temperature.	Depths in fathoms.	Temperatuəɹ.
Surface.	70° 0	72° 0	Surface.	77°·9
100	63·5	67·0	10	77·2
200	60·6	57·6	20	77·1
300	60 0	52·5	30	76·9
400	54·8	47·7	40	71·7
500	46·7	43 7	50	64·0
600	41·6	41·7	60	60·4
700	40·6	40 6	70	59·4
800	38·1	39 4	80	58·0
900	37·8	39·2	90	58·0
1000	37·9	38 3	100	55·6
1100	37·1	38·0	150	51·0
1200	37·1	37·6	200	46·6
1300	37·2	36·7	300	42·2
1400	37·1	36·9	400	40·3
1500	...	36·7	500	38·9
2700	35·2	..	600	39 2
2720	...	35 4	700	39·0
			800	39·1
			900	38·2
			1000	36·9
			1100	37·6
			1200	36·7
			1300	35 8
			1400	36·4
			1500	36·1
			Bottom.	34·7

It will not do as an objection to assert that, according to the gravitation theory, the ocean never attains to a condition of static equilibrium. This is perfectly true, as has been shown on former occasions*; but then it is the equator that is kept below and the poles above the level of equilibrium; consequently the disturbance of equilibrium between the equatorial and polar columns would actually tend to make the difference of level between the equator and the Atlantic greater than 3½ feet, and not less, as the objection would imply.

Another feature of this section irreconcilable with the gravitation theory is the fact that the warm water is all in the North Atlantic, and little or none in the South, a condition of things the reverse of what ought to be according to that theory. But according to the wind theory of oceanic circulation the explanation of the whole phenomena is simple and obvious. Owing to the fact that the S.E. trades are stronger than the N.E., and blow constantly over upon the northern hemisphere, the warm surface-water of the South Atlantic is drifted across the equator. It is then carried by the equatorial current into the Gulf of Mexico, and afterwards, of course, forms a part of the Gulf-stream. The North Atlantic, on the other hand, not only does not lose its surface-heat like the equatorial and South Atlantic, but, in addition, receives the enormous amount of heat constantly carried into it by the Gulf-stream. And the reason why the warm surface-strata are so much thicker in the North Atlantic than in the equatorial regions is perfectly obvious. The surface-water at the equator is swept into the Gulf of Mexico by the trade-winds and the equatorial current as rapidly as it is heated by the sun, so that it has not time to accumulate to any great depth. But all this warm water is carried by the Gulf-stream into the North Atlantic, where it accumulates.

North Pacific Ocean.—The temperature-soundings made in the U.S.S. 'Tuscarora' show that the North Pacific is much colder than the North Atlantic, and that the immense stratum of warm water found in the latter is wanting in the North Pacific. But as the North Pacific is almost entirely cut off from the cold Arctic basin, its waters, according to the gravitation theory, instead of being colder, ought to be much warmer than those of the Atlantic. It is found also that the North Pacific is actually warmer at latitude 52° than at latitude 43°, a fact also inconsistent with the gravitation theory, but easily explained by the wind theory.

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* 'Phil. Mag.' October 1871; 'Climate and Time,' Chapter ix.

The Southern Ocean.—The thermal condition of the Southern Ocean, as ascertained by the 'Challenger' Expedition, appears also irreconcilable with the gravitation theory. Between the parallels of latitude 65° 42′ S. and 50° 1′ S. the ocean, with the exception of a thin stratum at the surface heated by the sun's rays, was found, down to the depth of about 200 fathoms, to be several degrees colder than the water underneath. But, according to the gravitation theory, the colder water should be underneath.

The very fact of a mass of water 200 fathoms deep, and extending over 15° of latitude, remaining above water of 3° or 4° higher temperature, shows how little influence difference of temperature has in producing motion. If it had the potency which some attribute to it, one would suppose that this cold stratum should sink down and displace the warm water underneath. If difference of density is sufficient to move the water horizontally, surely it must be more than sufficient to cause it to sink vertically.

Exploration of the Pamir Steppe. By Colonel T. E. Gordon.

On Journeys in Paraguay in 1874–75. *By* Keith Johnston.

This paper* gave a general description of several journeys made in Paraguay during 1874-75, specially (1) of a journey through the old Jesuit mission-stations of Southern Paraguay bordering on the Paraná; (2) of another with the mixed commission, marking out the limits between Paraguay and Brazil on the north; (3) in Central Paraguay, during which a running survey was made of the chief interior river, the Tebicuary.

The paper further contained an account of the hydrography and extent of navigation in the rivers of Paraguay; the elevation of the country, especially of the northern watershed in connexion with barometric observations made for altitude; then of the population in numbers and race, and the distribution of the several tribes of independent Indians; concluding with a summary of the localities producing the Yerba-maté or Paraguay tea, the staple product of the country.

Report on the Progress of the Arctic Expedition and on the Proceedings of H.M.S. 'Valorous.' By C. R. Markham, *C.B., F.R.S.*

Himalayan Glaciers. By Colonel T. G. Montgomerie, *R.E., F.R.S., &c.*

The author made a brief reference to the general geography of India and the Himalayas. He pointed out the very great progress which had been made with the geography of Northern India, the Punjab, &c. since 1842, and more especially as to the exploration and survey of the Western Himalayas. In order to illustrate his paper he exhibited a large map of the Western Himalayas, showing the whole of the glaciers and the complete breadth of the Himalayan system from the Punjab to the plains of Eastern Turkistan, near Yarkund. The peaks and glaciers of this superalpine region were further illustrated by three large coloured sketches of portions of the Mustagh and Karakoram mountains, and by a section taken right through the mountains, which at this their narrowest part are 400 miles in breadth. He pointed out that the glaciers gradually increased in size from east to west, reaching their greatest development in the Mustagh range, where there are several glaciers over 20 miles in length, and the Biafo glacier 34 miles in length, and a great many from 10 to 20 miles in length. From a glance at the map it could be gathered that these glaciers covered a very large area. Colonel Montgomerie pointed out what a very important feature they formed in the geography of Asia, not only in a scientific point of view, but in a practical one, as they formed a vast natural reservoir, which provided an unfailing supply of water in a tropical country at a period when it was most wanted—that is, between the spring and the fall of the summer rains.

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* *Vide* 'Geographical Magazine,' parts 9, 10, 11 (1875).

Colonel Montgomerie pointed out that the Himalayan peaks rose to twice the height of those in the Alps, and that the glaciers were more than four times as long as those in the Alps, the Mer-de-glace (the longest) being hardly 8 miles in length, while those in the Himalayas were of all lengths up to 34 miles.

Prejevalsky's Travels in Mongolia and Northern Tibet.

By E. DELMAR MORGAN.

To the north-west of China proper lies a broad belt of hilly sandy deserts, 1400 miles in extent from east to west, which from the earliest historical times was a gathering-ground for the nomads of Inner Asia, whence they could descend on the populous but defenceless plains beneath, and pour a wave of conquest and desolation over the fertile provinces of the middle kingdom.

Ill adapted, owing to the poverty of its vegetation, to support a settled population, it nevertheless afforded a secure retreat to the robber and marauder, and was on this account a dangerous country for travellers. The Great Wall, which never protected China from her enemies, served to mark the limits beyond which civilized man could advance no further; and if the spirit of the nomad has been subdued after so many generations of Chinese sway, his native deserts remain unconquered and invincible as in the days when the Great Wall was built.

The further west the more bleak and desolate is the aspect of nature. The Great Wall still continues to define the limits of life and culture on the one side, of death and desolation on the other. Inside the northern bend of the Yellow River lies the country of Ordos, a sterile region of shifting sands, where many legends are still preserved of the great hero Jinghiz-Khan. To the west of the bend of the Yellow River is a region still more bleak and desolate, at one time the bed of a large lake; beyond it are the mountains which enclose the basin of Lake Koko-nor, and still further to the west grand snowy ranges and gradual ascents towards the uplands of Tibet. These are the regions visited by Colonel Prejevalsky, which few Europeans had ventured to penetrate previously. Marco Polo only devotes four short chapters of his first book to their description. Huc and Gabet traversed Southern Mongolia and passed by Koko-nor into Northern Tibet, but they gave no accurate geographical information. Père Armand David visited the mountains lying to the north of the great bend of the Yellow River, and made some interesting botanical researches; but he would not risk travelling through Kansu and Koko-nor, at that time disturbed by the Mahomedan or Dungan insurrection, of which our author gives a vivid description; Ney Elias also travelled through a part of the country about the same time. For the rest of our information we are chiefly indebted to Chinese records, fragments of which have been collected by Du Halde and Ritter.

Thus Prejevalsky's journey may really be termed a geographical feat, and will always hold an important place in science; for, besides his remarkable expedition from Dalai-nor to the Upper Yang-tsze-kiang, which alone would entitle him to the gratitude of men of science, he also made a march from Alashan to Urga (680 miles) across the Gobi in its widest part, which no one had hitherto attempted.

A recapitulation of all he has done and of the results obtained in the face of extraordinary difficulties would fill several pages; but as an English edition of his travels will shortly be published, those interested would do well to refer to it.

Expedition from the Lake Tchad to the Upper Nile. *By* Dr. G. NACHTIGALL.

On the Turcoman Frontier of Persia. *By* Capt. the Hon. G. NAPIER.

Exploration of the Aurès Mountains.

By Lieut.-Colonel R. L. PLAYFAIR, *H.B.M. Consul-General in Algeria.*

This part of Algeria has probably never before been explored by an English traveller, although lying close to the ordinary diligence-route between Constantine, or rather between Batna and Biskra.

Ptolemy places here his *Audon.* Procopius and other geographers speak of it as *Aurasion* or *Mons Aurasius*; but these hardly include the entire district now known as the Aurès Mountains, which may roughly be said to occupy the space between Batna and Biskra, eastwards towards the Tunisian frontier.

The inhabitants of this region are called Chawi, and are a branch of the Berber nation, to which the Kabyles also belong.

Colonel Playfair here traced the early history of this part of Numidia, and showed how one war of conquest after another had passed over it, and always with the same effect; the conquerors in their turn became the conquered, and were driven for safety to the mountains. Thus the Romans, when driven out by the Vandals, the Vandals after their defeat by the Byzantines under Belisarius, and the Byzantines when finally conquered by the Mahommedans—all sought and found a refuge in the Aurès Mountains, where they have left on the Chawi the imprint of their physical and moral character which fourteen centuries have not been able to obliterate. Light hair and blue eyes are frequently met with, and the average of female beauty is even higher than it is in England.

They observe the 25th of December as a feast, under the name of *Moolid,* or the birth, and keep three days' festival at springtime and harvest. Their language is full of Latin words; and they use the ordinary solar instead of the Mohammedan lunar year, the names of the months being almost identical with our own.

The Aurès range is a series of mountains running roughly parallel from N.E. to S.W., between which flow considerable rivers, of which advantage is taken with great skill to irrigate the valleys between them.

The great body of the drainage is from the southern side, where the rivers, after losing a part of their volume in irrigation, flow into the great marshy basin of Melghir.

The most important of these is the Oued Abdi, the hills on either side of which terminate in the two highest peaks in Algeria, Djebel Chellia on the left and Djebel Mahmel on the right; the former 7611 feet high, the latter scarcely lower.

In the plains and valleys considerable quantities of cereals are produced, and fruit cultivated to a great extent.

The inhabitants, unlike the Arabs, dwell in stone houses; the villages are perched high up on the sides of the hills, at short distances apart on both sides of the river; and the houses are generally so disposed that the roof of one is on a level with the floor of that above it, to which it actually forms a terrace.

The forests in the Aurès are very valuable, and have hardly yet been worked; they consist of cedar, oak, juniper, Aleppo pine, &c.; but it is sad to observe here, as almost everywhere else in Algeria, the scarcity of young trees, which are destroyed by the sheep and goats almost as soon as the seed germinates, and the destruction of the old ones by colonies of processional caterpillars, which establish their nests in the upper branches, and destroy all vegetable life as their ravages descend.

The mineral wealth of the Aurès is also very great, though hardly as yet more than suspected; in some places abundant indices of copper, lead, and iron were met with, and in one place what will no doubt prove a valuable mine of mercury and lead.

One can hardly ride a mile in the Aurès without meeting Roman remains of considerable importance, all testifying to the high state of civilization which existed wherever this great people founded colonies.

But it is principally on their northern slopes and in the plains at their base that those splendid cities existed, the ruins of which now excite the wonder and admiration of modern travellers. Bruce visited them a century ago, and made a large number of exquisite drawings of the principal architectural features. These are now in the possession of his descendant Lady Thurlow, by whose permission two of his original sketches were exhibited.

Commencing from Lambessa, a complete chain of these cities extended as far as Tebessa, their order from west to east being as follows:—

Lambees (mod. *Lambessa*), Verecunda (mod. *Markouna*), Thamugas (mod. *Timegad*), Mascula (mod. *Ain Khenchla*), Baghaia (mod. *Kast Baghai*), and Theveste (mod. *Tebessa*).

The first two of these are well known to travellers. Thamugas was described by Colonel Playfair in considerable detail. It contains numerous magnificent ruins, the principal of which are a triumphal arch, theatre, forum, capitol, a Byzantine fortress, and a Christian church. The whole surface of the ground is covered with fragments of sculpture and inscriptions, many of the latter quite entire, which prove that the city was founded by Hadrian, and colonized by the veterans of the 30th legion Ulpia after its return from the Parthian war.

Not far from Timegad is the fertile plain of Firis, on the west and south of which are two mountains covered with countless numbers of the most interesting megalithic remains. Their variety is considerable; but the most ordinary type is that of a low circular structure, nearly level with the earth at the upper part of its base, and varying in height on the opposite side, according to the slope of the hill, from 3 to 8 feet. The walls are of rough dry masonry, generally about 6 feet thick; the diameter is from 15 to 30 feet; and each contains a central chamber of irregular shape covered with a single slab of stone. In some places the monuments are close together; in others they are separated by a number of tombs of the ordinary dolmenic type, as if the latter were intended for people of less consideration than those for whom the circular ones were constructed.

The next city is Mascula, now Ain Khenchla, where an attempt has been made at European colonization. The position is well chosen from a sanitary and strategic point of view, but it is rather distant from any place where produce can be sold.

The ruins of Kast Baghai are also interesting; they are close to the diligence-route from Khenchla to Ain Beida. From the latter place to Tebessa is a day's journey, and here are to be found the finest Roman ruins in the colony. These consist of the ancient citadel restored by Solomon, the successor of Belisarius, who lost his life here. The modern city is built within it; there is a temple of Jupiter nearly complete, a magnificent quadrifrontal triumphal arch, and the ruins of a basilica, subsequently converted into a Christian church.

On the Physical Geography of that part of the Atlantic which lies between 20° N. *and* 10° S. *and extends from* 10° *to* 40° W. *By* Captain H. TOYNBEE, *F.R.A.S.*, *F.R.G.S.*, *&c.*, *Marine Superintendent of the Meteorological Office.*

The paper was accompanied by monthly diagrams, which showed:—

1st. The isobaric lines of mean pressure for each ·05 of an inch, together with arrows showing the prevailing winds and their force.

2nd. The isothermal lines for every second degree of air-temperature.

3rd. The isothermal lines for every second degree of sea-temperature, together with arrows showing the prevailing currents and their speed in 24 hours.

The author called attention to important facts relating to atmospheric pressure, temperature, wind, currents, weather, sea, clouds, natural history, earthquakes, &c.

The diagrams may be said to give the navigator a monthly picture of the doldrums, clearly showing him how in some months they are wedge-shaped (as remarked by the late Commodore Maury), and enabling him to select the best route across the equator. They illustrate the action of both air and water when meeting, as is constantly the case with the two trade-winds, and the currents which they produce, showing also how the air as well as water seems to eddy round a point of land *from* which the main stream is running.

They also illustrate some very sudden changes of temperature in both air and sea, for which the paper endeavours to account.

The paper also gives the specific gravity of the currents due to the N.E. and S.E. trades, as well as that of the Guinea current, which indicates that the latter is a surface back-drift above a colder current.

The district is the birthplace of many West-Indian hurricanes; and the place in which one originated was pointed out on the diagram for August, it having been afterwards traced to the island of St. Thomas. Besides many other allusions to remarkable and unsettled weather, the paper tells of five earthquakes which were experienced by ships in the district, two in 0° 30′ N. and 30° W., three in 1° S. and 20° W.

In the course of the paper frequent allusion was made to swells of the sea which had overrun by many hundreds of miles the winter gales which caused them, and seemed to be related to the rollers experienced at Ascension, St. Helena, and the West Coast of Africa.

The motion of upper clouds in relation to the direction of the winds was frequently remarked upon, their motion showing that the wind of one trade passed above that of the other at their equatorial verge; and, again, that above the south-westerly monsoon, which blows to the northward of the equator in certain months, the clouds very frequently move from the S.E. near the equator, and from the N.E. when further to the north.

Several allusions were made to the red dust which falls on ships at certain seasons, and to the cetacea, land and sea-birds, fish, and insects met with.

The whole paper may be said to be a *résumé* of a large work about to be published by the Meteorological Office, which is under the superintendence of the Meteorological Committee of the Royal Society, and is published *in extenso* as a non-official paper by that Office.

Changes in the Course of the Oxus. *By* Major HERBERT WOOD.

Trade-Routes to Western China. *By* Colonel YULE, *C.B.*

ECONOMIC SCIENCE AND STATISTICS.

Address by JAMES HEYWOOD, *M.A., F.R.S., F.G.S., Pres. Statistical Society, President of the Section.*

HAVING had the advantage of a school education in Bristol, I have noticed with interest, in subsequent years, the gradual development of this great city, and of its populous neighbour, Clifton; and I trust that the second visit of the British Association will be productive of benefit to your important district.

Railway communication, free trade, and the reduction of dock-dues have aided in increasing the commerce of this locality. Additional facilities for ocean steam-traffic will be afforded by the new docks alomst completed at the mouth of the river Avon; and fresh storage-room for timber, both by land and water, may also be expected in the same vicinity.

As an example of the utility of a free port, it may be mentioned that large supplies of grain arrive here in screw iron ships from the Black Sea and the Mediterranean. For barley, used for grinding, Bristol has now become the first provincial market in the empire. The imports of Messrs. Wait and James amounted, in 1874, to between 400,000 and 500,000 quarters of corn; and in one year (1874–75) 8,496,000 bushels of grain were landed in Bristol from foreign ports. The portion of England which may be supplied with grain from Bristol as a centre, extends in some directions for 100 miles.

Sugar-refining forms one of the ancient branches of industry both in Bristol and elsewhere; its extent may be appreciated from the establishment of Messrs. Finzel in this city, where 1200 tons of refined sugar can be turned out in a week.

French fiscal arrangements, however, are not favourable at the present time to the augmentation of British sugar-refineries; and the subject merits the attention of Members of the Economic Section.

Part of the French revenue is derived from taxes on spirits, salt, and sugar consumed in France. The duty levied in France on sugar, according to the 'Times' of the 28th July, 1875, when the sugar is sold for home consumption, equals in amount the value of the sugar.

A sugar is prepared by the French beet-root sugar-makers, looking as if it only contained 80 per cent. of saccharine matter in a given bulk or weight, whilst the sugar really contains 90 per cent. of saccharine matter. The raw sugar is assessed at a quality 10 per cent. below the real standard; and the French sugar-refiner is debited with a duty according to that assessment, and which is not paid.

When the sugar is exported, the actual quality of the sugar is taken, the drawback is set against the duty, and the refiner is paid the duty thus shown to be due to him.

A memorial issued by London sugar-refiners shows that in 1873 the quantity of
French refined sugar really produced was at least .... kilos. 174,859,000
and the "legal" equivalent of the refined sugar exported was.. „ 153,185,000
giving an excess over the "legal" quantity of .... „ 21,674,000
or about .... cwts. 413,000

In 1874 the excess over the "legal" equivalent of the refined sugar rose to 25,413,000 kilos., or about 498,000 cwts.

In 1873 the duty on that excess was...................... francs 15,891,000
and in 1874 .... „ 18,636,000
showing an increase of.................................. „ 2,745,000
or about.. £110,000 sterling.

If to this duty on excess, or bounty, amounting in 1874 to 18,800,000 francs per annum, be added the bounty derived from other sources, such as the "détaxe" on "poudres blanches," the total amount of bounty will be easily raised beyond 20,000,000 francs for sugar.

In English money 18,000,000 francs are equal to £720,000, paid by the French tax-payer to the French sugar-refiner, and with this result: the French sugar-refiner can sell refined sugar in a foreign market, such as England, below cost price.

From the 'Statistical Abstract' it appears that the import of foreign refined
sugar and sugar-candy into Great Britain in 1871 was.......... cwt. 1,460,102
and that it had increased, in 1874, to .... „ 2,717,406

The cheapness of refined sugar in Great Britain has augmented the average of consumption from 1 lb. a head in 1860 to 8½ lbs. a head in 1874.

Great Britain possesses commercial friends in France among the vine-growers of Bordeaux and Champagne, and the silk-manufacturers of Lyons. These great industries derive no profit either from a heavy tax on sugar consumed in France, or from a bounty enabling a French sugar-refiner to sell sugar in England below cost price. The occasion seems favourable for a remonstrance with the French Government, and for a conference with leading French statesmen connected with interests independent of beet-root sugar.

Beet-root grows admirably in England; and the British sugar-refiner may consider the question of extending in this country a valuable product of home agriculture.

To conduct a negotiation with France, a knowledge of the French language will be requisite for the Commissioners, whether appointed by private individuals or by the British Government.

It is gratifying to notice that in a recent revision of Bristol charities under the Endowed Schools' Commission, French has a place among educational requirements. Thus, in Queen Elizabeth's Hospital, now a boarding-school for 150 boys, after the entrance examination, which comprises reading, easy narrative, writing text-hand, and the first two rules of arithmetic, a scheme of school instruction is given, containing history and geography, as well as English grammar, composition, and literature, the elements of mathematics and natural science, the elements of French or Latin, or both, drawing and class-singing.

A similar entrance examination is arranged for admission into the Red Maids' Boarding-school for eighty girls, in Bristol, the income of which amounts to £4378 a year. In this School, instruction is given to girls in history and geography, English grammar, composition, and literature, the elements of mathematics and natural science, and of French or Latin, or both, drawing and class-singing, domestic economy, and the laws of health, needlework, and (if the Governors think fit) telegraphy, or some other branch of science having a bearing on skilled industry suitable for women.

The examination for admission to the Grammar School is to be graduated according to the age of the Candidate, and is never to fall below the following standard—that is to say, reading, writing from dictation, the first two rules of arithmetic, and the outlines of the geography of England.

The subjects of secular instruction in the Grammar School are to be as follows:—the Latin and Greek languages and literatures; the English language and literature; arithmetic and mathematics; history and geography; natural science and, in particular, applied mechanics, chemistry, and experimental physics; French and German; drawing; class singing.

An annual income of £1793 belongs to the Bristol Grammar School; and to this institution, as well as to Queen Elizabeth's Hospital and the Red Maids' School (all three being under the Bristol Municipal Charity Trustees), an augmentation has been arranged from various non-educational charities converted into educational endowments, of a capital sum of £14,500.

New buildings for 400 scholars are to be erected for the Grammar School, including a day- and boarding-school.

Colston's Hospital is a boarding-school for 100 boys, into which no boy is to be admitted under the age of ten years; and the scholars are not to remain after they are fifteen years of age. The examination for the admission of paying scholars comprises reading easy narrative, writing text-hand, and easy sums in the first two rules of arithmetic, and the multiplication-table. The Governors may raise the minimum standard from time to time if they deem it advantageous for the School to do so.

The subjects of secular instruction in Colston's boarding-school are arranged as follows:—reading and spelling, writing, arithmetic, and elementary mathematics; English grammar, composition, and literature; French or Latin, or both; the outlines of history; geography, political and physical; natural science; drawing and vocal music.

There will be two classes of scholars, foundationers and paying scholars. The foundationers in the boarding-school must have attended an elementary school regularly for a year preceding their application. They will be elected in order of merit, as tested in competitive examination for boys between ten and eleven years of age in the subjects of Standard IV. (Code 1875), as follows:—

> "To read with intelligence a few lines of poetry selected by the Inspector, and to recite from memory fifty lines of poetry.
>
> "To write eight lines slowly dictated once from a reading-book, and to show copy-books in improved small hand.
>
> "Compound rules of arithmetic (common weights and measures)."

A note is appended to the table of standards of examination in the new code of regulations, according to the 'Minute of the Committee of Council on Education,' 5th April, 1875, respecting the 4th Standard, that the "weights and measures" taught in public elementary schools should be Avoirdupois weight, long measure, liquid measures, time-table, square and cubical measures, and any measure connected with the industrial occupation of the district.

Bristol, from its geographical position, seems especially adapted for trade with the western part of the continent of Europe, where the metric system of weights and measures is now universally in use. Through various treaties of commerce British trade is rapidly increasing with countries employing that simple and easy mode of calculating measures and weights; and as a permissive Act of Parliament of 1864 sanctions the metric system in Great Britain and Ireland, it may be expedient for the Governors of Colston's boarding-school to consider if some knowledge of the tables of metric weights and measures may not be desirable for the foundationers of that venerable institution.

The competitive examination in Colston's boarding-school is arranged in the subjects of Standard V. of the Educational Code for boys between eleven and twelve years of age, as follows:—

> "Improved reading; and recitation of not less than seventy-five lines of poetry.
> "Writing from memory the substance of a short story read out twice. Spelling, grammar, and handwriting to be considered.
> "Practice, bills of parcels, and simple proportion."

The examination for admission to Colston's Girls' School is not to fall below the minimum standard for admission to Colston's Hospital.

The subjects of secular instruction are to be as follows:—Reading and spelling, writing, arithmetic or elementary mathematics; English grammar, composition, and literature; French or Latin, or both; the outlines of history; geography, political and physical; drawing and vocal music; household management; the laws of health; and needlework.

Besides the endowed schools of Bristol, Clifton College, in the immediate neighbourhood, founded in 1861, comprises 500 boys, in addition to whom there are 45 boys in the preparatory school of that College.

As soon as the boys of Clifton College reach the fifth form, they can enter either on the Classical or on the Modern side; but those who are not in the College are required to pass a preliminary examination.

In Clifton College instruction is given to boys intended for the Royal Military Academy, Woolwich, or the Indian Civil Engineering College, Cooper's Hill, or the profession of Civil Engineering; and a system of education is carried on suitable for students intended for either Oxford or Cambridge.

The Cathedral of Bristol assists in the establishment of a training College for the education of superior teachers; and for this institution the Ecclesiastical Commissioners provide a capital sum of £12,000.

An entrance examination is arranged for admission into the Training College, comprising English grammar and composition, arithmetic, geography, and English history. Afterwards another examination is held, in which each Candidate is expected to pass in at least two of the following subjects:—

> Divinity, English literature, Latin, one modern language, mathematics, and one branch of natural science.

No student is to be admitted until he has attained the age of 17 years.

Candidates may, if the Governors think fit, be admitted into the College without passing the examination for admission, if they are graduates of any university in the United Kingdom, or if they have passed the senior local examination of either of the Universities of Oxford or Cambridge, or the Matriculation Examination of the University of London, or if they are holders of any scholarship or exhibition which may be deemed by the Governors an adequate qualification.

The course of general instruction in the Training College has for its main object to illustrate methods of teaching, and the science and history of education, and to qualify the Students to become skilled teachers in higher schools. The course includes—

Lectures on the art of teaching;
Model lessons given to classes of scholars in the presence of Students;
Lessons, from time to time, given by Students to classes of scholars in the presence of the Principal or an Assistant Teacher, and under his tuition.

Once in every year there is an examination of the Students by an Examiner, or Examiners, appointed for that purpose by the Governors, and paid by them, but otherwise unconnected with the College. The Examiners report in writing to the Governors on the proficiency of the Students, as shown by the result of the examination, and on the ability which the Students evince in giving lessons to classes, and in the discipline and management of a school. The Governors are to communicate the report to the Principal of the College.

Entrance fees and tuition fees are determined by the Governors of the College, the rate for the tuition fees being not less than £20 a year.

The Principal is to receive a stipend of £200 per annum.

Near the top of Park Street, in this city, is the Bristol Museum and Library, the Council of which, in 1873, agreed with the Faculty of the Bristol Medical School to issue a circular setting forth the advantages of a technical college of science in Bristol for the west of England and South Wales. The Committee formed on this subject received a communication at an early period from the Master of Balliol College, Oxford, suggesting the cooperation of his own College, and probably that of another Oxford college in the undertaking.

A promise on the part of Balliol College and New College, Oxford, was afterwards given, to assist in the establishment and support of the proposed College by means of a yearly contribution of £300 each for a period of not less than five years, on condition of each Oxford college being represented on the governing body of the new institution, of the instruction given being literary as well as scientific, and of the requirements of adult education being specially considered. It was also provided that, so far as could be arranged, the instruction, other than that of the Medical classes, should be open to women, and that lectures should be given on general subjects. A ready assent to these conditions was accorded by the Committee who had taken charge of the negotiation.

In June 1874 the Mayor of Bristol presided at a public meeting in Clifton for the College. A scheme of constitution was prepared, and in 1875 a conference in favour of the College took place in one of the rooms of the Parliamentary palace in Westminster, attended by influential Members of both Houses of Parliament.

It may be of some value to friends of the Bristol College to hear some particulars of the development of Owens College, Manchester, in which I assisted as one of the original trustees of that seat of learning. At its origin the Trustees were satisfied to commence the College in a house with spacious apartments, to which was attached a gymnasium as an exercise-ground for the Students.

Chemistry and the English language are now especially attractive subjects in Owens College. Elementary history, Latin, mathematics, and mechanics, with jurisprudence and physiology, also command much attention among the Students.

Each Candidate for admission into Owens College usually produces a testimonial of good character from his last instructor. No person is admitted under the age of fourteen years; and those who are under sixteen are required to pass a preliminary examination in English, arithmetic, and the elements of Latin.

Periodical examinations are held in each class, and written exercises are given out. Neglect of these tests of progress disqualifies a Student from competing for prizes and honours at the end of the session, when a general examination takes place of all the Students. No certificate of attendance on the class is granted to a Student who absents himself, without a sufficient reason, from the general examination.

Mr. Greenwood, Principal of Owens College, reported in June 1874, that there were in that year 356 Students in the College, of whom 37 were under sixteen years of age, 117 between sixteen and eighteen, 75 between eighteen and twenty, and 127 above twenty. There were 141 medical Students and 847 evening Students. The total number was 1344 Students.

Owens College is affiliated to the University of London; and Greek is no longer compulsory in that University on Candidates at the Matriculation examination, but is ranked at that time as an optional subject, with French and German. Latin is compulsory at Matriculation; and a Student is required also to pass in any two of the three following languages—Greek, French, and German. The remaining subjects for Matriculation comprise mathematics, natural philosophy, chemistry, and English language and history.

It is recommended in Owens College, that if a Student elects to take up Greek, and either French or German for Matriculation, he should enter for the first year's Arts course, taking chemistry and one of the modern languages; and that those Students who propose to take up both French and German for Matriculation should enter for the first year's science course, taking Latin and both the modern languages of France and Germany.

In June 1873, at the Matriculation Examination of the University of London, 32 Students of Owens College passed; and 3 Students passed, in January 1874. Of these 35 Students, 7 were evening Students.

Students formerly at Owens College have obtained at Oxford a Stowell Civil-Law Fellowship at University College, a Burdett-Coutts Scholarship in Geology, a Fellowship at Pembroke College, and a Senior Mathematical University Scholarship, also an Exhibition and a Scholarship at Exeter College in natural science, and a Studentship in natural science at Christ Church.

At Cambridge an Owens-College Student has been rewarded by attaining the place of eighteenth wrangler in the Mathematical Tripos of 1874; and other Owens College Students have been elected to scholarships at Trinity College, St. John's College, and Sidney-Sussex College, and to a Sizarship at St. John's College.

Two Whitworth Scholarships have been gained by Owens-College Students.

In twenty-one years, from 1853 to 1874, there have been 234 Owens-College Students matriculated in the University of London, and 225 have successfully presented themselves at higher examinations of that University. During the three years 1871–74 seventy-one have matriculated, and seventy-five have passed the further examinations of the same University. Principal Greenwood observes that of the Owens-College Students a large body do not contemplate graduation either in London or elsewhere, and are yet in every sense devoted to academic work.

Prizes and scholarships are awarded to Students in the Medical department of Owens College; and the names of those who pass in universities and professional colleges are duly recorded in the Owens-College 'Calendar.'

A College for higher education at Bristol has a right to gather round it an ever-increasing number of students, and to give an importance to its own certificates and rewards, which will soon be appreciated as nearly equivalent to degrees in universities.

Girton College, three miles from Cambridge, affords an instance of lady students succeeding in the same academical examinations to which Cambridge-University gentlemen students are admitted. The Cambridge Examiners have kindly allowed marks to the papers of the lady candidates; and one lady student from Girton has recently obtained a few more marks than the highest gentleman student in the examination for the "pol.," or ordinary B.A. degree, at Cambridge.

Ladies who are ambitious of obtaining literary and scientific distinctions, seem to wish to enter the same examinations for which there are gentlemen candidates; and several lady students of Girton College have obtained places corresponding to that of Senior Optime in the Cambridge Mathematical Tripos, and of the second class in the Cambridge Classical Tripos.

The Middle-Class School in Cowper Street, London, under Dr. Wormell, has a high range of mathematical instruction; and the boys are encouraged to construct their own apparatus from simple materials, and to employ themselves in workshops recently added to the school. The English language and English history are admirably taught in that institution. The senior boys of the sixth form show a creditable knowledge of the elements of constitutional law and of political economy.

Ireland has of late years increased in prosperity from the more ready transfer of landed property in that island. The Irish Commissioners, under the Incumbered-Estates Act, commenced their sittings in 1849; and in 1868 an act was passed extending the powers of the Incumbered-Estates Court, for the sale of incumbered properties to properties that are unincumbered. A perpetual jurisdiction was granted to the new tribunal, under the name of the "Landed-Estates Court." In 1873 the amount of purchase-money for land under this Court was £1,737,222, the net rental of the land sold was £86,685, and there were 208 sales.

All Irish estates, whether incumbered or not, can be sold, or contracted for, or disposed of, through the medium of the Court, which is also judicially empowered to declare a title to property, and, by later acts, to sell or lease settled estates. Small purchasers of land would be benefited by a greater simplification of procedure, and a reduction of expense in the professional charges, which are fixed on a high scale. For instance, parties interested in the purchase of a farm worth £500 may be required, as a minimum expense, to pay nearly £100 in effecting the purchase.

Having visited the Landed-Estates Register Office in Boston, Massachusetts, I can report favourably of the excellent plan of recording transfers of landed property in the New-England States of North America. A book is kept, in which the description of each estate is preserved, and the mortgages and other claims on the land are entered. If a sale is intended, the person proposing to purchase may at once see the incumbrances on the property, as well as many particulars of importance respecting the value of the estate. The transfer of property after the sale is duly registered; and the new proprietor thus obtains his title to the land.

Next year (1876) a meeting of the International Statistical Congress is to be held in Buda-Pesth, the capital of Hungary. Official statistical representatives of all the principal governments of Europe, and of the United States of America, attend the Congress, which also includes delegates from statistical societies of different countries: it usually meets once every two years.

When the Congress assembled at Berlin in 1863 (under the presidency of Count von Eulenberg, Secretary of State for the Home Department in Germany), the statistical representatives of Great Britain comprised:—Dr. Farr, F.R.S., Superintendent of Statistics in the General Register Office; Mr. Valpy, Chief of the Statistical Department and corn returns in the Board of Trade; Mr. Hammick, Secretary of the General Register Office, and others.

On the 9th September, 1863, Mr. Valpy presented to the Congress the annual statement and the accounts of the trade and navigation of the United Kingdom of Great Britain and Ireland, and remarked that the International Congress was certainly doing good service to all nations. "The periodical meetings," observed Mr. Valpy, "which we are invited to hold in the capital cities, where the Members are received with such Royal and general kindness, must exercise a great and favourable influence upon public opinion in regard to national statistics. The opportunity afforded by the Congress for the meeting of public officers and gentlemen interested in statistics from so many countries is productive of much advantage. The circle of our friends is enlarged; and, speaking as an official delegate, I can say that our means of usefulness at home are increased, and our efforts of improvement are much encouraged, by the cordial personal intercourse between the Members of the Congress."

Dr. Farr, at the meeting in Berlin, eulogized the address of H.R.H. the late Prince Consort, who had presided at the opening of the International Statistical Congress in London. Dr. Farr mentioned that the labours of the Congress had been described in that inaugural address "as connected with the loftiest principles of philosophy, and directed to the noblest end—the good of the people of all nations."

Mr. Hammick thanked Dr. Engel, the Director of the Statistical Department in Berlin, for his able abridgement of the resolutions and works of the International Statistical Congress at its previous meetings.

The meeting at Buda-Pesth may have a special interest, as the Convention of Commerce between Great Britain and the Austro-Hungarian empire is liable to terminate on the 1st January, 1877, and commercial treaties with various other European states may also come under consideration, for modification or renewal, at the same time.

A valuable work on commercial treaties was published by Mr. Hertslet (formerly at the Foreign Office); and his son, Mr. Edward Hertslet, C.B., Librarian and keeper of the Papers at the Foreign Office, has recently prepared a collection of treaties, in one thin volume, showing how the trade between this country and Austria is regulated in the present year (1875).

Mr. E. Hertslet mentions the desire publicly expressed by Austria, Turkey, and other foreign powers to revise their commercial treaties not only with Great Britain, but with other states. He shows precisely in his treaties' collection what commercial treaties have been concluded between foreign states, containing clauses conferring more favourable treatment on their respective subjects, on commerce, and on navigation, than are specially provided for in the English treaties, but the benefits of which concessions are or might be enjoyed by British subjects under the "most-favoured-nation" clauses of the English treaties.

If the commercial treaties between different countries are likely to be considered at the Buda-Pesth International Statistical Congress, a calm and dispassionate survey of international commercial relations may be anticipated on the part of an assembly comprising official representatives of high statistical talent from nearly all civilized nations.

The Council of the Statistical Society of London nominates a small number of delegates to attend each Congress; and the Committee of Section F may perhaps arrange for some representation of the Section of Economic Science and Statistics in the Buda-Pesth Meeting of 1876.

In another department of statistical research, education, the General Committee of the British Association formerly voted grants, which materially aided educational inquiries. In 1836 the Report of a Committee of the Manchester Statistical Society (consisting of Messrs. W. R. Greg, W. Langton, and Henry Romilly), on the state of education in the borough of Liverpool, was presented to Section F at Bristol. The investigation had occupied thirty-one weeks, at a cost to the Society of £96. On the recommendation of the Sectional Committee in Bristol the sum of £150 was placed at the disposal of a Committee (consisting of Colonel Sykes, afterwards M.P. for Aberdeen, Mr. Hallam, and Mr. Porter, Secretary of the Board of Trade) in furtherance of inquiries into the actual state of Schools in England, considered merely as to numerical analysis; and similar grants were bestowed, with a like object, for several years in this Association.

Last year, at Belfast, some of the leading Members of the Statistical Section interested themselves in the restoration of harmony between the masters and the operatives in a strike which was going on at the time of the British-Association Meeting. A conference was recommended, happily followed by a compromise, and the differences were satisfactorily arranged.

At the present Meeting, the Section of Economic Science has various communications of much interest to be brought forward; and it gives me pleasure to request the reading of the first paper, thanking you, at the same time, for your courtesy in listening to my introductory observations.

On the probable Cost and Propriety of removing to England the fallen Obelisk of Alexandria, presented to Great Britain by the Pacha of Egypt. By Major-General Sir J. E. ALEXANDER.

On the Need of Systematic Observations on the Physical Characters of Man in Britain. By JOHN BEDDOE, *M.D., F.R.S.*

The writer endeavoured to show the need for the collection of extensive and systematic observations on the stature, bulk, weight, rate of growth, &c. of mankind in the British Islands. He had already laboured in this field for some time, but sought for more active cooperation from those interested. He pointed out how great results had already flowed from Quetelet's researches in this department of knowledge, and how the practical bearing of such statistics on factory legislation, on the recruiting question, &c. might be immediate and considerable.

On the Mortality of Adolescence. By JOHN BEDDOE, *M.D., F.R.S.*

This paper was founded on Mr. Charles Ansell's, jun., Statistics of Upper-Class Families. According to Mr. Ansell's figures, the mortality of upper-class girls, from 11 to 17 years of age, decidedly exceeds that of boys, and about 15 and 16 it actually surpasses, to a notable degree, that of both boys and girls of the lower classes, as inferred from the English Life Table. Beyond 17 the upper-class female mortality recovers itself, and remains very favourable throughout the remainder of life; while at the same age (17) the mortality of upper-class boys suddenly starts up, leaving below it first the upper-class female and then the lower-class male and female curves, and from 19 to 25 ranking worst of the four. A comparison of the statistics of childhood and youth, collected by Mr. W. Bowser, Rev. J. Hodgson, and others, confirms Mr. Ansell's facts. The excess of male upper-class mortality from 17 to 23 may be accounted for by that being the period of university and student life, of competitive examinations, sometimes of overstrain of mind and body, not unfrequently of fatal accidents, more often of dissipation and excess of various kinds. In the case of the excessive upper-class female mortality from 11 or 12 to 17 or 18, the connexion with the period of puberty is more obvious; and in relation to this must be mentioned the aggregate of influences which may be summed up in the term "school-life," and which affect upper-class but not lower-class girls. These considerations reinforce Sidney Smith's arguments against boarding-schools and in favour of the Scotch day-school system of education, at all events for girls during the age-period in question.

On the Death-rates of some Health-Resorts, and specially of Clifton.

By JOHN BEDDOE, *M.D., F.R.S.*

The conditions governing the relative mortality of towns fall under three heads, of which the second and third cannot be completely divided. These heads are Natural Climate, Artificial Climate, and Social Conditions, which last includes the amount and distribution of wealth, the prevailing occupations of the people, the degree of prevalence of drunkenness and vice, or of the improved habits which generally come with education, the proportions of sexes and ages in the population, the aggregation of individuals into masses, as in foundling hospitals, large schools, and barracks.

Advantages of the three kinds commonly go together: wealth seeks the best localities and provides itself with the best artificial climate. Towns containing a large proportion of well-to-do people can fairly be compared, as to their death-rates, only among themselves. For selecting such towns for comparison the excess of young women from 15 to 35 yields on the whole the best test; and on that principle the following Table has been constructed:—

Average Rates of Mortality for 1871 *and* 1872 *in Registrar-General's Subdivision.*

	Rate per 1000.	Ditto, exclusive of deaths in hospitals and Workhouses.
Westbury-on-Trym (including part of Clifton)...	14·5	14·5
Newton (Torquay)	16·2	16·1
Cheltenham	17·8	16·2
Clifton	16·3	16·3
Hastings (St. Mary)	16·9	16·6
Brighton (Kemp Town and Palace)	16·9	16·7
Teignmouth	17·2	17·0
Banwell (Weston-super-Mare)	17·7	17·3
Hastings..........	18·4	17·5
Leamington	18·7	17·9
Brighton	21·9	18·6
Bath (Bathwick, Lansdown, Walcot)	18·8	18·8
Bath (whole district)	21·4	18·8
Scarborough	23·0	21·4
Exmouth	21·7	21·6

In the succeeding years the death-rate of Clifton has been smaller; and even if all deaths of parishioners occurring elsewhere (in hospitals &c.) are added, the rate for 1873-74 is but 16·9, and for the last spring quarter 15·4, the zymotic rate being 1·4 per annum. It is doubtful whether anywhere in England an equal mass of population can be found yielding so favourable a rate. By Mr. Humphreys's method, the normal death-rate of Clifton would be 21·8, so that the actual rate is 4·9 below the calculated one.

On Sericiculture. By Mons. Bonhomme.

On Agricultural Statistics and Waste Lands. By William Botly.

The object of this paper was to show the utility of a better and more correct statistical publication of the amount of our cereal, root, grass, and other crops, cattle, sheep, swine, and horses. The author stated that the nations of antiquity, and even Peru at the present time, were much in advance of Great Britain and Ireland in carrying out this idea. In treating of waste lands, the total acreage of Great Britain and Ireland was stated to be 77,500,000, of which, in 1874, there were:—

In corn	11,364,834
Root and green crops	4,957,683
Flax, hops, bare fallow, clover, and other grasses under rotation	7,140,387
Permanent pasture, meadow, and grass, exclusive of mountain and heath	23,680,416

It is a most extraordinary fact that out of the total acreage of 77,500,000, there are no less than 30,356,680 unaccounted for.

The author suggested the propriety of the legislature offering secure inducements for the cultivation of waste lands.

On Workmen's Dwellings. By W. Botly.

On the Working of the Building Societies Act, 1874.
By E. W. Brabrook, *F.S.A., Barrister-at-Law.*

By this Act the rules of Building Societies are to be transferred from the custody of the Clerks of the Peace in the several counties to that of the Registrar in London. The Clerks of the Peace for some counties of importance have not yet effected the transfer, but the rules of 5157 societies have been received by the Registrar. Of these, it is probable that about 2000 are still in existence, the others having been, for the most part, terminating societies which had completed the period for which they were established.

Every society established after the passing of the Act has, and every society previously established may have, the privilege of incorporation. As yet, however, only 300 societies (of which 70 are new ones) have obtained certificates of incorporation. The certificate carries with it limitation of liability, and the right to borrow money to the extent of two thirds of the amount secured to the society by mortgages from its members.

The Act provides for the making annual returns to the Registrar by every incorporated society. Returns have not yet become due from the generality of societies; but those of 93 societies (42 incorporated, 51 not) already recorded at the Registry-office show a capital from share-subscriptions of £4,015,977, from borrowed money of £2,044,287, and from accumulated profit of £230,751, together £6,291,015; of which there was invested on mortgage £5,961,820, existing in other assets £328,918, and a balance deficient in one society of £257. The annual income of the 93 societies was £3,819,504.

The societies in Bristol and its neighbourhood are numerous and flourishing, and nearly all of them have become incorporated; but it is in the North of England building societies are most largely extended. The Queen's Building Society, Manchester, has an income of £734,578, and assets exceeding £900,000; the Leeds Building Society has 10,262 members, an income of £454,624, and assets amounting to £786,179. In London, also, are several very large societies.

On the Trade and Commerce of the City and Port of Bristol.

By LEONARD BRUTON, *Secretary to the Bristol Chamber of Commerce.*

The object of the paper was to point out the great advantages which had accrued to the trade and commerce and the general interests of the city and port of Bristol by the operations of the Bristol Docks Transfer Act 1848, and the consequent reductions in the dock dues. The reductions were very considerable, amounting to more than 50 per cent. on an average on vessels, and to about 20 per cent. on goods, that is, foreign produce imported.

Statistics were given of the import trade for 20 years before and 27 years after the reductions, which showed that, whereas in the first period, under the high dues, the progressive increase was at the rate of 33 per cent. on an average, dividing the 20 years into two decennial periods, a similar comparison for the 27 years since the reductions had been at the rate of 66 per cent. decennially.

A similar comparison with regard to the net rateable value of property within the municipal limits showed, that whereas the rate of increase before the reductions in the dock dues (that is, from 1841 to 1851) was 7 per cent., in the first period *after* the reductions it was at the rate of 16 per cent., comparing 1861 with 1851, and in the second period after the reductions it was 41 per cent., comparing 1871 with 1861.

Taking the extreme points, the foreign import trade of the port had increased 300 per cent., comparing 1848 with 1874; and the net rateable value of property had been nearly doubled between 1841 and 1871, viz. from £406,206 in 1841 to £719,913 in 1871.

Notwithstanding the reductions, the money receipts for dock dues had increased 50 per cent., and those for town and other port charges paid into the city chest amounted to three times more in 1874 than in 1847; and the city was receiving upwards of £12,000 more per annum from shipping than the amount of the rate on the fixed property towards the reductions in the dues.

Statistics were also given to show to what extent the *different branches* of the foreign import trade had increased since the reductions in the dues, viz.:—sugar, 126 per cent.; timber, 65 per cent.; grain flour, &c., 430 per cent.; hides, tallow, &c., 142 per cent.; and other produce, 139 per cent.

The paper referred also somewhat in detail to the general advantages which had resulted to *all* interests in the city—commercial, manufacturing, public improvements, docks, and railways, &c., and concluded by paying a tribute of respect to the late Mr. Robert Bright, an eminent merchant of Bristol, to whom, as the President of the Bristol Free Port Association from 1846 to 1850, the credit of this great change was chiefly due, and by regretting that the Corporation and the citizens had not more continuously and more fully carried out the Act of 1848, which had conferred such great benefits on the city and port of Bristol.

In reply to a question as to the rate of progress in other ports, statistics were read of the foreign import trade of the United Kingdom, which showed that it was increasing about 25 per cent. faster than that of Bristol before 1848, whilst since 1848 Bristol had recovered that lost ground, and was now keeping equal pace with the United Kingdom generally.

On the Principles of Penal Legislation.—Second Paper.

By JOHN T. BURT, *Chaplain of Broadmoor Criminal Lunatic Asylum.*

Montesquieu laid it down as one proposition in political science, that the monarchical governments of Europe were founded upon a principle of *honour*. Further, he contended that this principle of honour involved the setting of a low value upon life and of a high value upon property. This principle was strongly impressed upon the penal laws, which came down from former times. Assaults and injuries to the person, and even homicide, were purged by fines, offences against property were punishable with death.

The elements of social life have undergone great changes, and the relative value of life and of property has been reversed.

Penal legislation has followed slowly in the wake of these changes, and the severity of penalties against property has been mitigated.

The question is raised, whether the changes in penal legislation have been commensurate with the change in the relative value of life and property.

Two propositions are submitted:—

i. Assaults and injuries to the person are of the nature of offences against life.

ii. Imprisonment is of the nature of a penalty levied upon human life. It is a partial confiscation of human life.

Notwithstanding the recent changes in criminal law, offences against the person, in large classes of cases, are punished by penalties levied upon property.

On the other hand, offences against property are punished by a confiscation of some portion of human life.

This paper is limited to the consideration of offences against property.

A summary of the returns given:—In the year 1872-73 the number of sentences to either imprisonment or penal servitude for offences against property was 30,603.

The average daily prison population of all county and borough prisons, and of the so-called "Convict Prisons," was 27,193. It is estimated that of these nearly one third are sentenced for offences against property without violence.

Thus the result is arrived at, that the protection of property in England and Wales involves the confiscation of human life to an extent equal to the entire lives in constant succession of from 8000 to 9000 men, women, and children.

It is admitted that if the existing method of punishing offences against property could be proved by experience to be indispensable, then it ought to be adhered to. But unless such evidence could be adduced there is a strong presumption in favour of punishing offences against property by penalties levied upon property, and not by penalties levied upon human life.

Experience is strongly in favour of every change which has been effected in the direction of more merciful legislation.

The abolition of capital punishment for offences against property was a departure from the principle of the old law of the extremest kind. Other changes have followed. Nevertheless there has been a concurrent decrease of those forms of crime the penalties against which have been continuously mitigated.

There has been at the same time a constant decrease of severity in the sentences passed by exercise of the discretionary power vested in judges and magistrates. This passing of more lenient sentences is conclusive evidence that in the opinion of the judges, and of the whole magistracy of the country, the past changes in the law have worked satisfactorily.

The same general conclusion is supported by the testimony of Mr. Samuel Redgrave in the report for 1858, published in 1859.

Three cases within the personal knowledge of the writer adduced in illustration.

The same conclusion corroborated strongly by a return published by the Bank of England of the number of forged notes presented for payment before and after the abolition of capital punishment.

It is not contended that the decrease of crime is directly and altogether the result of the decrease in the severity of punishment. But in the face of all this evidence it is contended that the amount of crime is largely determined by other causal influences, and not mainly by the severity of punishment.

Whatever those other causal influences may be, no pretension is made that their force has been accurately measured. It will be impossible, therefore, to adduce proof that the limits of safety have been reached within which crime may be effectually controlled, and punishment be still further mitigated.

In one way the mitigation of penalties has to some extent contributed to the lessening of crime. It has brought the law more into accord with a natural sense of justice, the condition upon which the healthy and vigorous action of the law depends. This condition would be yet further fulfilled if offences against property were punished, so far as practicable, by penalties levied upon property.

The mitigation of penalties has contributed to the lessening of crime in another way.

It was one main argument with the advocates for the abolition of capital punishment for offences against property that the disproportionate severity of the penalty deterred injured persons from prosecuting and juries from convicting. But the effectiveness of penal law depends much more upon the certainty of punishment than upon the severity.

At the present time many persons are deterred from prosecuting, the punishment of imprisonment being often felt to be disproportioned to many offences against property.

This paper, and that read by the writer at Belfast, should be considered together.

On Industrial Schools. *By* Miss Carpenter.

Some Account of the Rise and Progress of the Sugar Trade in Bristol, 1875. *By* Henry Chamberlain.

The total consumption of sugar in the United Kingdom in 1874 was 719,343 tons. We trace sugar first from China, through Arabia, to Europe and the Canaries, from the latter imported into Bristol in 1526 and earlier. In 1506 the cane was taken to America, in 1614 first to Barbadoes, and from thence to other West-India Islands. Spain had, however, before this a large trade at St. Domingo. Barbadoes first exported sugar to England in 1646, and the West-India trade continued the principal one until 1844; then free labour of other places was admitted. One of our Bristol merchant's ancestors obtained estates in Barbadoes about the time of Cromwell's Protectorate in England, and some remain the family property to this day, and are still connected with this city. Other large mercantile houses were established here in the last century, and the import from the West Indies went on and flourished. From 1844 all kinds of sugar were imported, free and slave labour, and the duty was gradually removed, until in 1874 it was entirely abolished. The beet-root trade is protected in France, or it could not successfully compete with cane-sugar. In 1832, the year before slave emancipation, the total import trade into Bristol was 21,229 tons; in 1843, the year before the admission of free labour, 16,611 tons; from that time it rapidly increased to the large total of 94,528 tons in 1872, though 1874 is not so large, being 81,914 tons. These figures are from the Bristol Chamber of Commerce accounts. The entire import into England in 1700 was only 10,000 tons. In 1874 we have already seen it exceeded 700,000 tons, a wonderful increase. The future of this great trade is beyond all present calculation.

On Domestic Service for Gentlewomen. *By* Mrs. R. M. Crawshay.

On the Tanning of Sole-Leather in Bristol. *By* Sparke Evans.

On Indian Railways and Indian Finance. *By* Francis William Fox.

The object of this paper is to direct attention to the important bearing that the further extension of railways in India has upon the welfare of her people and the development of her resources.

The author showed:—

1st. That the land is capable of affording sufficient revenue for the general purposes of the government of the country and for the judicious development of public works, whilst at the same time allowing for the total abolition of the taxes on salt and opium.

2nd. That immediate steps should be taken to cover India with a network of railways.

3rd. That for the construction of the railways and working their traffic a new organization is required, as the existing system is not adapted for the special requirements of a country like India.

Before proceeding to consider these propositions, the author gave a few statistics of the Indian empire.

The total area of country under the administration of the Imperial Government is 1,558,254 square miles (or 997,282,560 square acres), of which 948,254 square miles (or 606,882,560 square acres) belongs to the British provinces, and about 610,000 square miles (or 390,000,000 square acres) to the native states.

The population, according to the last census returns, is about 240,000,000, of which about 193,000,000 belong to the British provinces, and 47,000,000 to the native states.

The density of the population in the whole empire is about 154 persons per square mile; or if the more important provinces only are taken, which form about one half of the whole area, the density would be about 234 persons per square mile; but in the North-West Provinces the average is 378, in Oude 465, in some of the Bengal provinces 500 to 573 persons per square mile, whereas in England the density of the whole population is 422 per square mile.

In Ireland the density is 166 persons per square mile.

The Indian railways opened and in course of construction at the commencement of 1873 were about 7722 miles, or one mile of railway to every 200 square miles of country, whereas in England there is one mile of railway to every 4¼ square miles of country, and in Ireland one mile of railway to every 16⅓ square miles of country.

The Indian railways, as above, have cost about £97,000,000, or £16,536 per mile.

The Irish railways have cost about £16,000 per mile; and by a curious coincidence the gross receipts per mile per annum on the Indian and Irish railways are almost identical.

In India the gross receipts are about	£1148	per mile
In Ireland	1142	„

The total receipts on the Indian railways for the financial year of 1873 were £6,742,789, the net revenue £3,185,000, which gives a percentage of about 3¼ per cent. per annum on the outlay; or, if the railways had been made, as they might have been, upon a cheaper and more economical system, or for, say, about £8000 per mile, the percentage upon the outlay would have been 6½ per cent. per annum.

The gross revenue of the Indian Government for the financial year ending March 1873 was £50,110,215, or nearly £2,000,000 in excess of the normal expenditure.

Of this revenue £44,449,000 were realized as follows:—

From land, and contributions from native States ..	£22,000,000
From salt	6,165,000
From opium	8,684,000
From Customs, Stamps, and Excise	7,600,009

But the cost of collecting the salt and opium duties is about £2,290,612; so that if these two taxes were abolished the amount derived from them, viz. £14,819,000, would have to be reduced by this sum of £2,290,612, which would leave £12,528,388 to be provided for.

Assuming the population of India, as per last census returns, is 240,000,000, and that every person, including rich and poor, expended upon an average, on their food and clothing, one penny per day, this would give a sum equal to £365,000,000 per annum; would not this amount give us approximately the value of the produce raised off the land per annum? For may not the value of the exports, amounting to about £55,227,495 per annum, be fairly set off against the imports, which amount to about £31,260,561, and the value of the labour required to convert the produce of the land into food and clothing and convey them to the market?

In this expenditure of £365,000,000 per annum, the author has estimated that 200,000,000 of the population expend only ½*d.* per day per person.

Of the 994,130,560 acres belonging to the British states, we cannot estimate that there are less than 250,000,000 of acres under cultivation, or say about one fourth of the whole area.

This may be considered an under-estimate, as Sir George Campbell considers there is a much larger area of land under cultivation than this.

Owing to the depressed condition of the Indian agricultural labourers (they being only half-fed and clothed), the land is nearly everywhere imperfectly cultivated. If the condition of the agricultural labourer was improved, we may safely estimate that the value of the produce of the land off the same cultivated area would be increased at least 25 per cent.

The revenue from the land is derived by certain assessment charges of so much per acre, which to all intents and purposes is simply an ordinary rent charge; but owing to the different and varied forms of land-tenure throughout India created or endorsed by the Imperial Government, the rent-charges vary considerably and are based upon no uniform principle.

In addition to the rent-charge there is a special charge made per acre for those lands which are directly or indirectly benefited by irrigation, and which charges enable the Government to realize a profit (according to Lord G. Hamilton) of about 5 per cent. upon all the large sums which have been expended upon irrigation works.

From the imperfect state of land registration, a large area of cultivated land probably escapes altogether paying any rent to the imperial revenue.

It seems just and expedient that the revenues of India should be made dependent and should be realized on the produce of the land, and not from the land itself.

The revenue would thus increase as the prosperity and wealth of the people advanced, and there would exist a powerful stimulant to develop and ameliorate the condition of the millions of her people.

Simultaneously with the introduction of raising the revenue from the produce of the land, the duties upon salt and opium should be abolished.

If the revenue from the land was to be raised by a charge of one tenth on the value of the produce, which is the ancient Oriental standard of rent, this value being estimated, as above, at £365,000,000, the amount of this revenue would be about £36,500,000, and would increase annually as the resources of India were increased in value by the extension of railways and spread of irrigation works, and by the improved purchasing power of the people.

This revenue would show an excess of £16,500,000 per annum over the normal expenditure of a financial year like that ending March 1878; but this surplus would have to be reduced by £12,528,388, on account of the abolition of the salt and opium taxes, leaving still a surplus of about £4,000,000, which surplus would be an annually increasing one on account of the progressive value of the land revenues.

Let us assume that only two thirds of the 1,558,254 square miles would be provided with railways.

This area, divided by 20, will give us about 50,000 miles of railways that would be ultimately wanted in order to give India about half the railway accommodation that Ireland has, or about 42,000 miles would have to be constructed in addition to those already finished and in course of construction during, say, the next 25 years.

If these 42,000 miles of railway are made, as they can be, for about £6000 per mile, under conditions to be hereafter specified, the total cost of these 42,000 miles would be £252,000,000, which added to the £100,000,000 approximately already expended, gives £352,000,000 as the ultimate capital to be invested in Indian railways, an amount equal to about the value of one year's produce of the land, assuming that the produce is only £365,000,000; but it must be remembered that of the £252,000,000 to be expended, about £126,000,000 would be expended in England in purchase of rails, railway-plant, rolling-stock, freight, and profits.

The interest upon £352,000,000 at 5 per cent. amounts to £17,600,000 per annum; although we are aware that the required capital could be raised at 4 per cent., we have allowed 5 per cent. interest, as it offers a premium for private enterprise to embark more readily into Indian railways.

Assuming the average gross receipts of the whole of the Indian railways amounted to only one half of the average receipts of the Irish lines, or say to £572 per mile per annum, or £11 per mile per week, and allowing the working expenses, say, to be 66 per cent. of the gross receipts, the net amount available to meet the above 17,600,000 would be £9,724,000, leaving a deficiency of £7,876,000.

The deficiency on account of the guaranteed interest for the year ending March 1875 is £1,428,442, which deducted from the £7,876,000 shows an increased charge when the works are all completed, say some 25 years hence, of £6,447,558 per annum. This would be provided for by the surplus of the revenue, which, as before shown, would in the first year be about £4,000,000, and would be increasing yearly.

The author proposed that the same principles which have been found by experience successful in private industrial enterprises should be applied as far as possible to those of the State.

Close personal attention must be given to details, in combination with a capacity for generalizing these details so as to mould the whole into an effective and complete organization.

As the author believes it is a first essential for the successful development of Indian railways that the spirit and enthusiasm of private enterprise should be enlisted, he suggested that a scheme somewhat similar to the following might be adopted with advantage. That the railways should be the property of the State, and the working of the traffic within certain specified limits to be under its supreme control.

It will be necessary for obvious reasons that the 42,000 miles of new railways referred to above should be very approximately located, and, for the sake of convenience, divided into three classes.

The first-class railways should be those which would cost about £5000 per mile.

The second class those which would cost £6000 per mile.

The third class those which would cost £8000 per mile.

The average of the whole to cost about £6000 per mile. The Government would then proceed to offer to approved parties concessions of certain railways on terms somewhat to the following effect:—

1st. The land to be provided free of cost.

2nd. All materials required for the construction and equipment of the railway to be imported free of duty, and to be carried at special low rates over the railways in operation.

3rd. That interest at 5 per cent. per annum should be guaranteed on the standard cost of the railway.

4th. The said guarantee of 5 per cent. should come into operation only and when certain lengths or sections of a railway have been certified to be completed and equipped with rolling-stock in conformity with the concession.

5th. That the concessionaire would have to work the traffic of the railway subject to certain Government regulations, and maintain it in working order to the approval of the Government for a term of, say, 35 years, determinable by the Government at the end of every seven years.

6th. The concessionaire would have annually to pay to the Government in monthly instalments an amount equal to the Government guarantee of 5 per cent., after which all the receipts of the traffic would belong to the concessionaire.

7th. That for those railways where the annual net receipts will not cover the guaranteed interest after the said railways have been opened and at work for three years, then the Government shall allow an abatement off the annual payment, such abatement to be assessed by an approved court of appeal.

8th. That the concessionaire shall have the power of issuing ordinary shares unguaranteed by Government not exceeding, say, £4000 per mile, the Government not to be liable to purchase these ordinary shares at the end of the

35 years, but the said shares would remain the property of the holders and shall participate in all the profits after the guaranteed interest and working expenses have been paid.

It will be readily seen that in the foregoing scheme capitalists in England and India would be attracted to embark with spirit and energy into Indian railways, as there exists many important elements for realizing substantial profits in proportion as the collateral trade in connexion with the traffic of a railway became developed, which elements, most must admit, are sadly wanting in the present organization of Indian State Lines, whilst at the same time it embraces all the advantages (and these are many) of the railways being owned and under the control of the State.

*On the Standard of National Education**. *By* Mrs. William Grey.

The object of this paper is to draw some practical inferences from that on the study of Education as a Science, read last year at Belfast, the most important of these being that which forms the title. The definition of education in the former paper, as the direction given to the development of the human being by the external influences brought to bear upon him, aiding, arresting, or distorting his growth, which applies to national as to individual education, will include under that name all direct instruction and influence, together with the indirect pressure of the social atmosphere and general conditions under which we live. It is on this indirect and apparently uncontrollable social element that a national standard of education would exercise the most powerful influence; for every nation, class, and profession, having any vigorous life, has an ideal of what its members should be, which affects each individual in them by a public opinion more potent than any law Some such ideal of education does indeed exist now in all classes of society, and creates a standard for each class. The question is, whether it is an adequate one, judged from a general, not a class, point of view, and whether the scientific study of education would not give us one universally applicable and resting on the firm ground of principle. The scientific view, taking human nature as its basis, makes that principle the equable development of all the powers and faculties in their due relation to each other.

To begin with physical training: we have the Greek ideal preserved to us in their statues, and should adopt it for ours, making our drill, gymnastics, and physical exercises for both sexes parts of a really scientific physical training, directed to attain the maximum of strength and grace, and reduce to a minimum weakness and deformity. This would give importance to the conditions of healthy development before and after school-life, and scientific unity to our sanitary legislation, coordinating every measure to the same end, the improvement of our human breed, hitherto infinitely less regarded than that of our cattle.

Passing on to intellectual education, our ideal must include here also not only development but harmony, the balance of intellectual forces which constitutes soundness of mind and their due subordination to the supreme end of intellectual life, right reasoning, the discernment of the true relations to ourselves and each other of the objects and persons making up the world in which we live. Hence the standard of intellectual education should be the formation of a sound judgment, which exercised on common things is no other than common sense, and in the region of abstract thought is the discovery of truth. How to attain this standard by directing all our school teaching towards it, is a problem the science of education has still to solve; for the testimony of examiners of every degree and for every profession may be appealed to to prove that it is not solved yet, and that the development of intelligence producing a high average of reasoning power is not the general result of our present methods of teaching.

In the higher education given at the Universities, or whatever corresponds to them, knowledge ceases to be a means only, and becomes an aid in itself, but should lead to another end not less worthy, *i.e.* culture. This, which is too often supposed to be mere ornament, has a high educational value by giving a keener edge to our judgment, and training reason to deal with human probabilities, and to weigh evidence coloured by human feeling, which physical science does not bring before it. Assuming, on the authority of Mr. M. Arnold and other competent persons, the notoriety of, at least, very common failure on the part of our schools and universities to produce the culture their whole system is directed to attain, it may be attributed, first, to the absence of a high national standard of culture as the necessary crowning of the educational edifice; and, secondly, to the need of science to discover and correct the defects in our methods whence it proceeds.

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Following the natural order of human development, we come next to moral education. In the moral as in the intellectual constitution we find a hierarchy of powers, and one supreme over the rest. This is conscience, the voice within us pronouncing on right and wrong, and determining the obligation expressed by "I ought" and "I ought not." The establishment of this rightful supremacy, the subjection to it of the desires, affections, passions, making "I will" wait upon "I ought," is the ideal of moral education. Here we have a recognized standard, that of Christian morality; but there is too much evidence to prove that it is not the practical and efficient one. How it is to be made efficient, how our moral teaching is to become as practical as it is universal, and establish the sovereignty of conscience "*de facto*" as well as "*de jure*," are questions on which the honour and prosperity of the country depend; and where can we find their solution except in the science of education, which is in fact the applied science of human nature?

Over the religious element of our nature, potentially the noblest, but also the root of our worst evils, superstition, fanaticism, and bigotry, education has almost unbounded power, and it has the highest standard, that of Christ, and an ideal of divine loveliness in the life of Christ. Many of the causes of the notorious failure of our religious teaching in producing corresponding results lie outside the scope of this essay, and the subject is mentioned only to point out that the standards of intellectual and moral education are most powerful factors in religious education, and that when we have trained the intellect to form sound judgments and the moral nature to obey conscience, we shall have laid the best foundation in human power for religious training up to the Christian standard.

All that has been said hitherto applies equally to both sexes; but this paper would be incomplete without some mention of the standard of education for women. Practically there is no such standard above that of the elementary schools, and the whole subject is in a chaotic state, tossed on the horns of conflicting opinions between the extremes of absolute dependence on the pleasure and convenience of men and absolute equality with them. Yet a high standard of womanly worth and dignity is the very salt of a nation's life, without which it slowly rots to the core. To the English ideal of the purity and sanctity of home presided over by the wife and mother, incomplete and inconsistently acted upon as it is, we owe whatever we have of wholesome social life. But there are signs of a change for the worse even here; and considering that the unavowed but real standard held up to women from their cradle is to please men, and that experience early teaches them that men as a rule are best pleased by beauty and fashion, most easily won by the wiles of coquetry, and most effectually repelled by any independent exercise of thought and judgment, the wonder is that so much goodness, truth, and sound-heartedness is left among them. Professor Max Muller, after saying to the writer that the future of England depended on her young mothers, asked, "How are they to be educated?" Can there be any question in the whole range of scientific investigation more worthy to occupy our ablest minds, and the solution of which is more important to the welfare of the nation and the human race?

Mr. Matthew Arnold has a passage showing the necessity of a nation's action being inspired by an ideal commanding the respect of the many, in order to keep that nation together and give it unity and true greatness. The practical comment on these words, based not on theory but the history of the decline and fall of nations, is this: Of all ideals giving a nation unity and greatness, the most powerful is a high ideal of national character, of what its men and women, its gentlemen and gentlewomen should be; and of all sciences giving us the command over the forces of nature, the most important is that which will give us command over the forces of the human heart and mind, and enable us with approximate certainty to educate the nation up to its ideal.

On Income Fallacies and some of their Consequences. By P. Hallett, *M.A.*

The object of this paper is to show that the word "income" has unequal meanings and values in its applications to different sources, and that therefore its use as a comparative measure either of wealth or taxation without previous correction must necessarily lead to error. These inequalities arise from the unequal degrees in which different sources are naturally reacted on in the production of incomes, and from the variable manner in which these reactions are recognized by present modes of assessment. Nominally equal incomes are only really equal when they leave the things that produce them, considered as values, equally unimpaired, or when they leave them equally restored. £100 of income produced by a source that remains permanent in value is a very different thing from £100 produced by a source that is consumed in and by the very process of its production. To yield the one may require a capital value of £2000; the other may arise from a value varying from below £2000 down to even less than the £100 of income itself, simply according to the rate of the source's consumability. But the two are called equal incomes, and are treated as equal both in statistics and legislation. To incomes that leave their sources unimpaired belong the ordinary interest of money and, with some slight drawback, the rent of land. To those that consume their sources belong terminable annuities, the royalties of mines, the rent of houses, the income or wages of labour in its various forms, in all of which the income is increased at the expense of the source. In the one category the income is a pure profit on the source's capital value; in the other, besides pure profit, it contains the repair and redemption-funds of its capital value, or, in other words, is a mixture of profit and capital.

Different classes of income thus being of unequal constitution, their units are necessarily of unequal denomination, and are therefore, as such, incapable of being added, subtracted, or of forming comparative ratios. Various fallacies arise from ignoring these inequalities. (1) In estimating, for example, the National Income, land-rent, house-rent, industrial and professional incomes, and even common wages, have all been added together as if the income units of each class were of the same value; and the incongruous mixture has even been capitalized at pure interest rates in order to obtain the increment of National Wealth. (2) Again, in estimating the comparative incidence of General Taxation on different classes of persons or property, the same oversight has been committed. Income, according to the ordinary rule, has been taken as the comparative measure of incidence, but the measure not being of common value in different classes the comparison fails radically. If one class of incomes pays 11 per cent. of taxation and another class pays 14 per cent., but the income unit of the one is of more than double the value of that of the other, the percentages, without correction, are evidently scientifically worthless and practically misleading. (3) The same error that thus applies to taxation in general applies to the special Income-Tax; and it is indeed probably owing to the mode in which different denominations of income are officially defined and treated in the income-tax administration that the preceding fallacies have arisen.

As these consequences (statistical and legislative) result from a want of uniformity in the idea of income, their true remedy would appear to consist in supplying this want; and as the want arises from the unequal degrees in which the different sources are impaired through production, it would be supplied by restoring this impairment. Such restoration will generally imply a deduction from the incomes of terminating sources, as at present given, of repair or redemption funds sufficient to make the capital value of these sources permanent. The sources being thus rendered economically permanent the incomes would be permanent also, whilst their units being of the same denomination might be added, subtracted, or employed as comparative measures of taxation without error or injustice.

If, using symbols, P be a source's production, E its productive expenditure or consumability, I its true income or profit, then I will be determinable by the formula $I = P - E$. Income will be thus universally definable as the difference between production and its cost—the pure excess by production above capital, the source's pure profit or permanent annual value.

On the Progress of the Coal Question.

By Professor W. Stanley Jevons, *F.R.S.*

The purpose of this paper is to compare statistical facts concerning the recent progress of the output of coal with various predictions and theories which had been published on the subject in the previous fifteen years. The quantity of coal raised in the United Kingdom in the year 1873 amounted to the enormous weight of 127,000,000 tons, according to the mineral statistics of Mr. Hunt. Professor Hull, in his valuable work on the English Coal-fields, had questioned the power of the coal-fields to admit of a much greater drain in any one year than 100,000,000 tons, at which rate he believed the supply would be sufficient for eight centuries. Facts now entirely negative the hypothesis of any such fixed limit.

Sir W. Armstrong, in his Presidential Address of 1863, put forward his celebrated calculation, that the produce of coal was advancing by a uniform arithmetic annual addition of 2¾ millions of tons, at which rate the coal in the country, as then estimated, would last only 212 years. According to this law of increase the produce in 1873 ought to be 119 millions, which is 8 millions *less* than the truth, the increase in the interval being at least 41 millions, instead of 33 millions, as it would be according to Sir W. Armstrong's method of calculation. The annual average addition to the output is now nearly 3½ millions of tons, instead of 2¾ millions; but the true law cannot really be that of arithmetic increase, which, if followed backwards, would lead us to zero about the year 1830.

The true law of increase is that of a geometrical series, with the average annual ratio of 3½ per cent. According to this law, as described in the 'Coal Question' in 1865 (1st ed. p. 213, 2nd ed. p. 240), it was calculated that the produce of coal in 1871 would be about 117·9 millions. According to Mr. Hunt's statistics it proved to be actually 117,352,028 tons. On the same method of calculation the produce of 1873 would be about 126·3 millions; and the actual quantity raised, as already stated, exceeds this by about 700,000 tons. In spite of the extraordinary rise of price of coal in the years 1872 and 1873, the law of geometric increase is thus remarkably verified.

In the Report of the Royal Commission on Coal some calculations of Mr. Price Williams are put forward, in which the average consumption (apart from exportation) of coal per head of the population is assumed as rising from 3·9636 tons in 1871, to 4·4266 tons in 1881, 4·5786 tons in 1891, and so on, to a maximum of 4·6526 tons in 1941. But, according to this method, the *consumption* (not including coals exported) of the year 1873 would be nearly 6 millions less than the truth. Mr. Price Williams believed that the rate of increase of consumption of coal per head had passed its maximum, and was declining, whereas the most recent statistics show that between 1869 and 1873 the advance was more than double that in the interval 1865–69. The whole theory of Mr. Williams rested upon the assumption that there was a continuous decease in the rate of increase of the population, whereas his own tables showed that this increase was, in the last decade (1861–71), 11·736 per cent. compared with 11·197 per cent., that of the decade 1851–1861.

It is further pointed out that the remarks of the Commissioners upon the "Coal Question" proceed from an entire misapprehension of the arguments given in that book. No one asserted that the production of coal in Great Britain ever would rise to the higher quantities given by the geometric law of increase. The true conclusion drawn was, "*that we cannot long maintain our present rate of increase of consumption; that we can never advance to the higher amounts of consumption supposed. But this only means that the check to our progress must become perceptible within a century from the present time.*"

In the year 1872 the price of coal rose in many places to a height two or three times its previous highest amount. This rise was in some respects exceptional, but was mainly due to the increased demand which, in spite of the enormous price, advanced 5 per cent. per annum. The great increase in the number of collieries produced by the extraordinary demand, will no doubt render the price more moderate for some time to come; but the coal famine of the years 1872–73 may be regarded as the first twinge of the scarcity which must come, and it has taught us that coal has now become the first necessary of life in this kingdom.

On the Influence of the Sun-spot Period upon the Price of Corn.
By Prof. W. STANLEY JEVONS, *F.R.S.*

On the prevailing Mode of Preparation for Competitive Examinations.
By D. MACKINTOSH.

On the Value of European Life in India in its Social, Political, and Economic Aspects. By F. J. MOUAT, *M.D., F.R.C.S., formerly Professor of Medicine and Medical Jurisprudence in the Medical College of Calcutta, &c.*

The intention of this paper is to show that the high mortality rates which have heretofore prevailed in India among civil and military lives were not necessarily due to climatic causes or to unavoidable tropical risks, but were largely attributable to bad hygienic conditions, imprudence of living, unnecessary or reckless exposure, and similar agencies. All of these were shown to be either removable by sanitary measures or to be so much within the personal control of individuals as to reduce the inevitable risks to life of residence or service in India to a very moderate degree above the chances of prolonged existence in more temperate climates. In support of this view carefully prepared tables were produced of the deaths and invaliding among the European officers of H.M. British forces serving in India from 1861-70 inclusive. In these tables proof was afforded that in India diseases of the abdominal organs take the place of the contents of the chest in Great Britain as causing mortality, and that phthisis alone in the latter country destroyed a larger ratio of persons in the active period of life than cholera, hepatic disease, and dysentery combined did of Europeans in India; while from all ordinary causes and diseases there was no material difference between the casualties of India and those of England.

The gradual diminution of the death-rate in the English army in India within the present century from 69 to 15 per thousand, the reduction of the ratio for civil life in the covenanted services in a similar proportion, and the ascertained death-rate of carefully selected European railway employés in India, 10 per 1000, were all shown in their bearings on this great and important question.

The conclusions at which Dr. Mouat arrived were, that in carefully selected lives of persons of prudent habits, in moderately comfortable circumstances, the risks to life in India were so little above those of England as to render it perfectly safe to insure those lives at English rates, which rates are known to be largely in excess of the estimated and ascertained value of selected lives at home at corresponding ages.

Dr. Mouat also considered briefly the question of the colonization of India by European settlers. This he regarded very much as a question of race; and while he doubted the possibility of such colonization of tropical plains by the inhabitants of Northern Europe, he was of opinion that on the Steppes of Central Asia and the mountain-ranges of Hindostan it would be possible to rear as healthy, vigorous, manly, and intelligent a people as in any country in the world.

As a social problem it was of great importance to determine that health and strength could be maintained in India at no undue risk; as a political question it had equally important bearings on the large drain upon the manhood of Great Britain necessary for the maintenance of our Eastern Empire; and as an economic question it was scarcely secondary in interest, as affording a wide and productive field for English capital and enterprise in assisting to develop the vast resources of that great dependency of England.

On Legislative Protection to the Birds of Europe.
By C. O. GROOM NAPIER, *F.G.S., M.A.I.*

The author said that in 1864 he brought before the Association ten Tables on the Food of Birds as a plea for their legislative protection.

Having published the paper in the form of a small book, he had received acknowledgments from members of the Committee in the House of Commons on the Wild Birds' Protection Bills that his work had been the text-book of thei

Committee in the matter. He therefore wished to urge legislation in foreign countries with a view of preventing the diminution of insectivorous birds, especially which wintered in the south, and maintaining strongly the immense advantage of protecting birds in the breeding-season as a means of increasing vastly the value of agricultural crops, and affirmed that the two years' experience of good crops in England since the passing of the Act of 1872 was a proof of the correctness of his statement. With a view of putting this thoroughly to the test, he challenged all who were willing to join issue with him in the matter, both farmers, gardeners, landholders, sportsmen, and naturalists, to produce facts and be ready to answer his statement before the British Association next year. He stated he had had the thanks, through their ambassador Count Munster, of the Imperial German Government for his information with reference to legislation in Europe on the matter, and was therefore anxious that the benefits of following the example of England might be apparent. The author reviewed the European species with reference to their economic value, and had in his hand recorded facts for the good of each bird.

On the Acclimatization of the Silkworm. *By* MRS. BLADEN NEILL.

Building Societies and the Act of 1874. *By* THOMAS FRANCIS PEACOCK.

Building Societies are of three classes, Permanent, Terminating, and "Bowkett." Hitherto they have been governed by an Act passed in 1836 (6 and 7 Wm. IV. c. 32); but the recent Act (37 and 38 Vic. c. 42) removes several practical difficulties in their working. These are (1) :—In the mode of raising capital, the new Act giving a limited power to borrow money; (2) in the liability of Members, the new Act expressly limiting it to the moneys paid or to the amount secured by mortgage; (3) in joint Membership, the new Act expressly authorizing it, (4) in payments to representatives of deceased Members, which may now be made up to £50 without administration, (5) in the security to be given by Officers, which is now required from every officer having receipt or charge of money of the Society; (6) in the investment of surplus funds, which is now permitted on all the securities usually open to Trustees; (7) in Societies uniting or transferring their engagements, which is now authorized and regulated; (8) in winding up, which is now made easy and inexpensive; (9) in the settlement of disputes, which may now be referred either to arbitrators, to the County Court, or to the Registrar, by either of whom a case may be stated for the supreme court or discovery granted; and (10) in uncertainty of legislation, which is now removed by the Statute being a consolidation with amendments of the law on the question. The advantages offered by the Act are so important that Building Societies of all classes should avail themselves of them by becoming incorporated.

On the Industrial Position of Women as affected by their exclusion from the Suffrage. *By* A. M. PRIESTMAN.

The industrial resources of a people are best developed when every one exercises his faculties fully.

In England the tendency is towards this ideal condition: more men of the upper ranks are engaged in trade and commerce now than formerly, and fewer men in the lower ranks are injuriously overworked. This tendency, however, though strongly marked amongst men, is not noticeable amongst women. The duties of mere housekeeping are lighter than when brewing, spinning, &c. were done at home; whilst those women who have to work for their bread are increasingly unable to gain employment, and those who have work are beset year by year with new drags and difficulties. In some callings higher education is required than used to be the case, and the educational standard is lower for girls than for boys, so they cannot compete fairly. Trade-unions forbid their members to take girls as apprentices, so women cannot become skilled workers. The laws of the country hamper and harass women while they leave men free, so that the industrial value of women's work has sunk so low that in this city of Bristol women may be found making shirts for 2½*d.* each.

The improvement in the industrial value of men's work has always grown out of certain political conditions. Industrial progress and political freedom are so closely united that John Bright spoke at a meeting of trade-unions and trade societies in 1866 and said:—"Your duty, your obvious duty, a duty from which you cannot escape," is to bring all your organization to bear "on the working out of your political redemption." The homes, the wages, the wealthy unions of enfranchised artisans, contrasted with the condition of unenfranchised agricultural labourers, seeking charity to fly from their tumble-down cottages and hopeless future here for lands across the sea, bear out the wisdom of his words.

Why should not working women benefit, as working men have done, by the same means? It is said that they do not stand in need of the suffrage because in all ranks men and women are so closely connected that the interests of every class of women are watched over by some men as if identical with their own The weakness of this assertion is shown by the fact that men make laws for women which men in the same position of life reject for themselves. The Factory Act of 1874 was pressed upon the consideration of Mr. Mundella by working men. As a boon for working women, many of the factory women were very much against it, for they saw that less work meant less food or clothing; some of them in Leeds had an interview with the candidates for the representation of the borough, and urged their views with cogent reasoning, they were as courteously received as non-electors usually are. But the folly of electors has more weight in Parliament than the common sense of the unrepresented The Factory Act became law, and Parliament lent itself to one of the worst mistakes of the first Trade-Unions; for to limit the wages of men to one standard and to make a hard and fast line for the length of time women shall work, though different in detail, are one in principle. Women's wages have already been reduced in many places where the Act applies; women lose by the shilling or sixpence taken off their wages, and the country loses by the lesser productiveness of the 392,986 hands employed in the manufacture of textile goods. Working women are beginning to be alarmed at the dangers which threaten them, and are forming unions for their own protection. At the Trades Congress in January last, an excellent letter was read from Mrs. Paterson, the Secretary of a League in London; and the National Union of working women sent a delegate, to endeavour to dissuade the Congress from pressing for further legislative restriction. The Congress strongly condemned such legislation for men, but upheld it for women; they said they were acting entirely in the interests of women: and two delegates said women ought to be prevented from working in some trades altogether, for the work was not fit for them; and added, they took lower wages than men, and brought men's wages down. A new element was here brought into the discussion, but no one took any notice of this; and with only one dissentient (the women's delegate) it was agreed that the Parliamentary Committee should endeavour to obtain an extension of the Factory Act to other trades where women are employed.

Women would not work twelve or fourteen hours a day for a mere pittance if they could earn bread more easily, nor follow repulsive callings if lighter trades were open to them. It is clear that the interests of working women are not represented by the class of men to whom they belong, and that the industrial position of women is suffering at their hands. The policy is as short-sighted as it is selfish; for if women have to live at all they must eat; and if they are shut out from industrial pursuits, they must live on the earnings of others, either on money supplied directly by individuals or indirectly by the State. A country must lose in wealth if a number of its inhabitants, who could be productive labourers, are made idle by force. If women worked for their own bread, they would spend their money again, and stimulate other trades. Productive industry is in itself so expansive, that no one can determine the bounds which it shall not pass. In England, where the employers of labour are ever supplementing the toil of the workman by new inventions, new machinery, there must be room for more labourers if the laws or the usages of society did not hold them back. The difficulty women find in getting work is not because there is none in the country to be done, but because they are held in by artificial barriers, within which they crowd and jostle and tread one another down in a terrible struggle to live. If these arbitrary hindrances were taken away, the industrial efforts of women would find ample and enriching scope; to do this, to remove these barriers, they must have their due share in the unmaking of those laws which now hedge them in on every side. Those whom Government can afford to forget must not expect to be fairly dealt with by the law. Not working women only but all women suffer. The loss from waste labour is not greater than the loss from waste thoughts prevailing up and down the kingdom in women's minds. Incentives to industry that are powerful for men are wanting to women.

On Free Trade in Labour. *By* D. A. Spalding.

Statistics of Free Public Libraries. *By* Miss Stamp.

On the Comparative Mortality of Abstainers and Non-Abstainers from Alcoholic Liquors. *By* E. Vivian, *M.A.*

From the returns of the United Kingdom Temperance and General Provident Institution established on the 31st December, 1840, exclusively as a Total Abstinence Life Assurance Society, to which a second department, open to the General Public, was added in the year 1847, the following statistics were given :—

I. Pecuniary Results, as shown by the Reversionary Bonus declared on the Premiums during successive quinquennial periods —

Year	Section.	Per cent.		Mean per cent.	Difference
1860.	Total Abstinence	35 to 86	=	61	20
„	General .	26 to 59	=	41	
1865.	Total Abstinence. .	24 to 56	=	40	6
„	General	17 to 52	=	34	
1870.	Total Abstinence .	34 to 84	=	59	25
„	General	20 to 49	=	34	

From this it appeared that the advantage in favour of the Total Abstinence Department was, in the five years ending 1860, as 61 to 41; in the period ending in 1865 as 40 to 34; and in 1870, as 59 to 34.

As it might have been objected that the pecuniary results were affected by the varying amounts of the claims under the Policies in the several Departments, it was considered advisable to calculate the expected and actual deaths; the following were the results.—

	In the Total Abstinence Department.		In the General Department.	
	Expected Deaths.	Actual Deaths.	Expected Deaths.	Actual Deaths.
1866-70	549	406	. 1008	944
(five years).	Difference	–143	Difference	–64
1871-74	561	390	994	1027
(four years).	Difference	–171	Difference	+33
Totals (nine	1110	796	2002	1971
years).	Difference	–314	Difference	–31
	viz. 25 per cent. below the average.		viz. 2 per cent. below the average.	

In the last Report of the Institution presented at the Annual Meeting on May 25, 1875, the Actuary reported the Mortality on Whole Life Policies to have been as follows:—Expected Claims in the Total Abstinence Department 153, for £29,648; Actual Claims 110, for £24,683.

In the General Department—Expected Claims 263, for £54,092; Actual Claims £578, for 28,006.

On the Science of Capital and Money. *By* W. Westgarth.

MECHANICAL SCIENCE.

Address by WILLIAM FROUDE, *Esq., C.E., M.A., F.R.S., President of the Section.*

THE address of the President of a Section would year by year possess an appropriate interest, if it could always consist of an exposition of the progress made during the past year in the department of science which the Section embraces. And many of the addresses to this and other sections have conformed to this pattern with marked success.

But the adequate preparation of an address shaped in this approved mould would require a range of experience and a grasp of thought such as few possess; and custom has wisely sanctioned a type of address which, though less appropriate to the occasion, need not be either uninteresting or inapposite. And we, in this Section, have not to search far for instances in which its President has charmed and instructed us by a masterful exposition of some single subject in practical science, or by a timely reminder of the improvident manner in which we deal with some precious store of natural wealth.

I must express a hope that it will not be regarded as a conversion of liberty into licence, if the subject I have chosen obliges me to introduce a further innovation, and to use diagrams and experiments in order to make my meaning clear.

I propose to treat of certain of the fundamental principles which govern the behaviour of fluid, and this with special reference to the resistance of ships. By the term "resistance" I mean the opposing force which a ship experiences in its progress through the water.

Considering the immense aggregate amount of power expended in the propulsion of ships, or, in other words, in overcoming the resistance of ships, I trust you will look favourably on an attempt to elucidate the causes of this resistance. It is true that improved results in ship-building have been obtained through accumulated experience; but it unfortunately happens that many of the theories by which this experience is commonly interpreted are interwoven with fundamental fallacies, which, passing for principles, lead to mischievous results when again applied beyond the limits of actual experience.

The resistance experienced by ships is but a branch of the general question of the forces which act on a body moving through a fluid, and has within a comparatively recent period been placed in an entirely new light by what is commonly called the theory of stream-lines.

The theory as a whole involves mathematics of the highest order, reaching alike beyond my ken and my purpose; but I believe that, so far as it concerns the resistance of ships, it can be sufficiently understood without the help of technical mathematics; and I will endeavour to explain the course which I have myself found most conducive to its easy apprehension.

It is convenient to consider first the case of a completely submerged body moving in a straight line with uniform speed through an unlimited ocean of fluid. A fish in deep water, a submarine motive torpedo, a sharp-ended sounding-lead while descending through the water, if moving at uniform speed, are all examples of the case I am dealing with.

It is a common but erroneous belief that the resistance to its onward motion experienced by such a body thus moving, originates in an increase of pressure throughout its head end, and a diminution of pressure throughout its tail end. It is thus supposed that the entire head end of the body has to keep on exerting pressure to drive the fluid out of the way, to force a passage for the body, and that the entire tail end has to keep on exerting a kind of suction on the fluid to induce it to close in again—that there is, in fact, what is termed plus pressure throughout the head end of the body and minus pressure or partial vacuum throughout the tail end.

This is not so; the resistance to the progress of the body is not due to these causes. The theory of stream-lines discloses to us the startling but true proposition, that a submerged body, if moving at a uniform speed through a perfect fluid, would encounter no resistance whatever. By a perfect fluid, I mean a fluid which is free from viscosity, or quasi-solidity, and in which no friction is caused by the sliding of the particles of the fluid past one another, or past the surface of the body.

The property which I describe as "quasi-solidity" must not be confused with that which persons have in their minds when they use the term "solid water." When people in this sense speak of water as being "solid," they refer to the *sensation* of solidity experienced on striking the water-surface with the hand, or to the reaction encountered by an oar-blade or propeller. What I mean by "quasi-solidity," is the sort of stiffness which is conspicuous in tar or liquid mud; and this property undoubtedly exists in water, though in a very small degree. But the sensation of solid reaction which is encountered by the hand or the oar-blade is not in any way due to this property, but to the *inertia* of the water: it is in effect this inertia which is erroneously termed solidity; and this inertia is possessed by the perfect fluid with which we are going to deal, as fully as by water. Nevertheless it is true, as I am presently going to show you, that the perfect fluid would offer no resistance to a submerged body moving through it at a steady speed. It will be seen that the apparent contradiction in terms which I have just advanced is cleared up by the circumstance, that in the one case we are dealing with steady motion, and in the other case with the initiation or growth of motion.

In the case of a completely submerged body in the midst of an ocean of perfect fluid, unlimited in every direction, I need hardly argue that it is immaterial whether we consider the body as moving uniformly through the ocean of fluid, or the ocean of fluid as moving uniformly past the body.

The proposition that the motion of a body through a perfect fluid is unresisted, or, what is the same thing, that the motion of a perfect fluid past a body has no tendency to push it in the direction in which the fluid is flowing, is a novel one to many persons; and to such it must seem extremely startling. It arises from a general principle of fluid motion, which I shall presently put before you in detail—namely, that to cause a perfect fluid to change its condition of flow in any manner whatever, and ultimately to return to its original condition of flow, does not require, nay, does not admit of, the expenditure of any power, whether the fluid be caused to flow in a curved path, as it must do in order to get round a stationary body which stands in its way, or to flow with altered speed, as it must do in order to get through the local contraction of channel which the presence of the stationary body practically creates. Power, it may indeed be said, is first expended, and force exerted, to communicate certain motions to the fluid; but that same power will ultimately be given back, and the force counterbalanced, when the fluid yields up the motion which has been communicated to it, and returns to its original condition.

I shall commence by illustrating the action on a small scale by fluid flowing through variously shaped pipes; and I must premise that in the greater part of what I shall have to say, I shall not require to take account of absolute hydrostatic pressures. The flow of water through pipes is uninfluenced by the absolute pressure of the water.

I will begin with a very simple case, which I will treat in some detail, and which will serve to show the nature of the argument I am about to submit to you.

Suppose a rigid pipe of uniform sectional area, of the form shown in fig. 1 (Plate IX.), something like the form of the water-line of a vessel.

The portions A B, B C, C D, D E are supposed to be equal in length, and of the same curvature, the pipe terminating at E in exactly the same straight line in which it commenced at A, so that its figure is perfectly symmetric on either side of C, the middle point of its length.

Let us now assume that the pipe has a stream of perfect fluid running through it from A towards E, and that the pipe is free to move bodily endways.

It is not unnatural to assume at first sight that the tendency of the fluid would be to push the pipe forward, in virtue of the opposing surfaces offered by the bends in it—that both the divergence between A and C from the original line at A, and the return between C and E to that line at E, would place parts of the interior surface of the pipe in some manner in opposition to the stream or flow, and that the flow thus obstructed would drive the pipe forward; but if we endeavour to build up these supposed causes in detail we find the reasoning to be illusory.

I will now trace the results which can be established by correct reasoning.

The surface being assumed to be smooth, the fluid, being a perfect fluid, can exercise no drag by friction or otherwise on the side of the pipe in the direction of its length, and in fact can exercise no force on the side of the pipe, except at right angles to it. Now the fluid flowing round the curve from A to B will, no doubt, have to be deflected from its course, and, by what is commonly known as centrifugal action, will press against the outer side of the curve, and this with a determinable force. The magnitude and direction of this force at each portion of the curve of the pipe between A and B are represented by the small arrows marked *f*; and the aggregate of these forces between A and B is represented by the larger arrow marked G. In the same way the forces acting on the parts B C, C D, and D E are indicated by the arrows H, I, and J; and as the conditions under which the fluid passes along each of the successive parts of the pipe are precisely alike, it follows that the four forces are exactly equal, and, as shown by the arrows in the diagram, they exactly neutralize one another in virtue of their respective directions; and therefore the whole pipe from A to E, considered as a rigid single structure, is subject to no disturbing force by reason of the fluid running through it.

Though this conclusion that the pipe is not pushed endways may appear on reflection so obvious as to have scarcely needed elaborate proof, I hope that it has not seemed needless, even though tedious, to follow somewhat in detail the forces that act, and which are, under the assumed conditions, the *only* forces that act, on a symmetrical pipe such as I have supposed.

Having shown that in the case of this special symmetrically curved pipe the flow of a perfect fluid through it does not tend to push it endways, I will now proceed to show that this is also the case whatever may be the outline of the pipe, provided that its beginning and end are in the same straight line.

Assume a pipe bent, and its ends joined so as to form a complete circular ring, and the fluid within it running with velocity round the circle. This fluid, by centrifugal force, exercises a uniform outward pressure on every part of the uniform curve; and this is the only force the fluid can exert. This pressure tends to tear the ring asunder, and causes a uniform longitudinal tension on each part of the ring, in the same manner as the pressure within a cylindrical boiler makes a uniform tension on the shell of the boiler.

Now, in the case of fluid running round within rings of various diameter, just as in the case of railway trains running round curves of various diameter, if the velocity along the curve remain the same, the outward pressure on each part of the circumference is less, in proportion as the diameter becomes greater; but the circumferential tension of the pipe is in direct proportion to the pressure and to the diameter; and since the pressure has been shown to be inversely as the diameter, the tension for a given velocity will be the same, whatever be the diameter.

Thus, if we take a ring of doubled diameter, if the velocity is unchanged, the outward pressure per lineal inch will be halved; but this halved pressure, acting with the doubled diameter, will give the same circumferential tension.

Now this longitudinal tension is the same at every part of the ring; and if we cut out a piece of the ring, and supply the longitudinal tension at the ends of the piece, by attaching two straight pipes to it tangentially (see Plate IX. fig. 2), and if we maintain the flow of the fluid through it, the curved portion of the pipe will be under just the same strains as when it formed part of the complete ring. It will be subject merely to a longitudinal tension; and if the pipe thus formed be flexible, and fastened at the ends, the flow of fluid through it will not tend to disturb it in any way. Whatever be the diameter of the ring out of which the piece is assumed to be cut, and whatever be the length of the segment cut out of it, we have seen that the longitudinal tension will be the same if the fluid be moving at the same velocity; so that, if we piece together any number of such bends of any lengths and any curvatures to form a pipe of any shape, such pipe, if flexible and fastened at the ends (see fig. 3), will not be disturbed by the flow of fluid through it; and the equilibrium of each portion and of the whole of the combined pipe will be satisfied by a uniform tension along it.

Further, if the two ends of the pipe are in the same straight line, pointing away from one another (see Plate IX. fig. 4), since the tensions on the ends of the pipe are equal and opposite, the flow of the fluid through it does not tend to push it bodily endways*.

This is the point which it was my object to prove; but in the course of this proof there has incidentally appeared the further proposition, that a flexible, tortuous pipe, if fastened at the ends, will not tend to be disturbed in any way by the flow of fluid through it. This proposition may to some persons seem at first sight to be so paradoxical as to cast some doubt on the validity of the reasoning which has been used; but the proposition is nevertheless true, as can be proved by a closely analogous experiment, as follows:—

Imagine the ends of the flexible tortuous pipe to be joined so as to form a closed figure (see fig. 5), there will then be no need for the imaginary fastenings at the ends, since each end will supply the fastening to the other. Then substitute for the fluid flowing round the circuit of the pipe, a flexible chain, running in the same path. In this case the centrifugal forces of the chain running in its curved path are similar to those of the fluid flowing in the pipe; and the longitudinal tension of the chain represents in every relevant particular the longitudinal tension on the pipe.

As a simple form of this experiment, if a chain be set rotating at a very high velocity over a pulley in the manner shown in fig. 6, it will be seen that the centrifugal forces do not tend to disturb the path of the running chain; and indeed, the velocity being extremely great, the forces, in fact, tend to preserve the path of the chain in opposition to any disturbing cause. On the other hand, if by sufficient force we disturb it from its path, it tends to retain the new figure which has been thus imposed upon it (see fig. 7).

The apparatus with which I am about to verify this proposition has been lent to me by Sir W. Thomson. It is one which he has used on many occasions for the same purpose; and I must add that the proposition in his hands has formed the basis of conclusions incomparably deeper and more important than those to which I am now directing your attention.

You observe, the chain when at rest hangs, in the ordinary catenary form, from a large pulley with a very wide-mouthed groove and mounted in a frame which is secured to the ceiling. By a simple arrangement of multiplying bands the pulley is driven at a high speed, carrying the chain round by the frictional adhesion of its upper semi-circumference. When at its highest speed the chain travels about 40 per second.

The idea that the chain when thus put in motion will be disturbed by its centrifugal force from the shape it holds while at rest, must point to one of two conclusions; either (1) the chain will tend to open out into a complete circle, or (2) it will on the contrary tend to stretch itself at its lower bend to a curvature of infinite sharpness.

But you observe that no tendency to either change of form appears. On the contrary, the chain, instead of taking spontaneously any new form in virtue of its centrifugal force, has plainly assumed a condition under which it is with difficulty disturbed, alike from its existing form, or from any other which I communicate to it by violently striking it. Such blows locally indent it almost as they would bend a bar of lead.

In spite, however, of this quasi-rigidity which its velocity has imparted to it, it does, if left to itself, slowly assume, as you perceive, a curious little contortion, both as it approaches and as it recedes from the lower bend of the catenary; and it is both interesting and instructive to trace the cause of the deformation.

I have already explained that the speed of the chain subjects it throughout to longitudinal tension. Speaking quantitatively, the tension is equal to the weight of a length of the chain twice the height due to the velocity. This is $\frac{v^2}{g}$; and this, as the speed is about 40 feet per second, $=\frac{1600}{32}=50$ feet, or with this chain about 14 lbs.

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* See Appendix, Note A.

Now in travelling through the lower bend of the catenary, the chain passes from being nearly straight, to being sharply curved and immediately straightened again; and this change of form involves a continued pivoting of link within link, the friction being called into action by the tension which presses the surfaces together. Each link thus in succession resists this pivoting with a definite force, and the resistance, in effect, converts what appears to be a perfectly flexible combination into one possessing a tangible degree of stiffness; and the oblique attitude assumed by the chain as it approaches the bend, and the slight back turn which it assumes as it emerges from the bend, are alike consequences of this factitious stiffness.

For, in virtue of gravity, the running chain, like the chain at rest, tends always to maintain the original catenary; and in virtue of its speed of rotation, it seeks to maintain (not preferentially the catenary, but) whatever form it for the moment possesses. Hence its departure from the true catenary was, as you saw, gradual. But when the figure of equilibrium is once attained, the persistency of form imparted by velocity, serves to maintain this figure as indifferently as any other. Hence the figure is that in which equilibrium subsists between the force of gravity seeking to restore the catenary, and the factitious stiffness resisting the necessity of bending and unbending.

The slowness with which the form is assumed, and its steady persistency when once assumed, alike bear witness to the truth of the proposition which it is the object of the experiment to verify.

The stream of fluid in the tortuous flexible pipe would behave in a strictly analogous manner.

It might at first sight appear that I have now the materials for the proof of my chief proposition, the assertion of the unresisted progress of a submerged body; for such a body might be assumed to be surrounded by a system of imaginary pipes, as shown in Plate IX. fig. 8; and each of these pipes being in equilibrium endways, that is to say, the flow of fluid through it not tending in the aggregate to move it endways, neither, it might be said, would the flow of fluid tend to move the submerged body endways. But this reasoning would not be sound. The pipes we have hitherto been considering have been of uniform sectional area throughout their length, an assumption which has been necessary to the treatment pursued, as the velocity has in each case been assumed to be uniform throughout the pipe. The section of the pipe may have been square, circular, trapezoidal, or any other form; but the area of the section has been assumed to be the same throughout the length of the pipe.

But pipes of uniform sectional area do not truly represent the flow of a fluid past a submerged body. I shall presently ask you to consider the fluid as flowing past the body through a system of imaginary pipes; but to render the assumption admissible, the sides of the imaginary pipes must not be so placed as to interfere with the established course of the fluid, whatever that may be; in other words, if, for the sake of illustrating the behaviour of the fluid, we assume that it is divided into streams or filaments flowing through imaginary pipes, we must accept such a form for those imaginary pipes that their sides exactly follow the path of the adjacent particles of fluid.

Now such a rule may, and probably will, require the imaginary pipes to be of varying sectional area throughout their length. Therefore, before we can apply the analogy of the flow of fluid through pipes to the flow of a fluid past a submerged body, it is necessary to consider the behaviour of fluid in pipes of varying sectional area.

It is, I think, a very common but erroneous impression, that a fluid in a pipe exercises, in the case of its meeting a contraction (see fig. 9), an excess of pressure against the entire converging surface which it meets, and that, conversely, as it enters an enlargement (see fig. 10) a relief of pressure is experienced by the entire diverging surface of the pipe. Further it is commonly assumed that, when passing through a contraction (see fig. 11), there is in the narrow neck an excess of pressure due to the squeezing together of the fluid at that point.

These impressions are in no respect correct; the pressure at the smallest part of the pipe is, in fact, less than that at any other point, and *vice versâ*.

If a fluid be flowing along a pipe which has a contraction in it (see fig. 12), the forward velocity of the fluid at B must be greater than that at A, in the proportion in which the sectional area of the pipe at B is less than that at A; and therefore while passing from A to B the forward velocity of the fluid is being increased. This increase of velocity implies the existence of a force acting in the direction of the motion; that is to say, each particle which is receiving an increase of forward velocity must have a greater fluid pressure behind it than in front of it; for no other condition will cause that increase of forward velocity. Hence a particle of fluid, at each stage of its progress along the tapering contraction, is passing from a region of higher pressure to a region of lower pressure, so that there must be a greater pressure in the larger part of the pipe than in the smaller, and a diminution of pressure at each point corresponding with the diminution of sectional area; and this difference of pressure must be such as to supply the force necessary to establish the additional forward velocity required at each point of the passage of the fluid through the contraction. Consequently, differences of pressure at different points in the pipe depend simply upon the velocities at those points, or, in other words, on the relative sectional areas of the pipe at those points*.

It is simple to apply the same line of reasoning to the converse case of an enlargement. Here the velocity of the particles is being reduced through precisely the same series of changes, but in an opposite order The fluid in the larger part of the pipe moves more slowly than that in the smaller, so that, as it advances into the enlargement, its forward velocity is being checked; and this check implies the existence of a force acting in a direction opposite to the motion of the fluid, and each particle being thus retarded must therefore have a greater fluid pressure in front of it than behind it; thus a particle of fluid at each stage of its progress along a tapering enlargement of a pipe is passing from a region of lower pressure to a region of higher pressure. As is well known, the force required to produce a given change of velocity is the same, whether the change be an increase or a decrease. Hence, in the case of an enlargement of a pipe, as in the case of a contraction, the changes of velocity can be satisfied only by changes of pressure, and the law for such change of pressure will be the same, *mutatis mutandis*.

In a pipe in which there is a contraction and a subsequent enlargement to the same diameter as before (see fig. 11), since the differences of pressure at different points depend on the differences of sectional area at those points, by a law which is exactly the same in an enlarging as in a contracting pipe, any points which have the same sectional area will have the same pressures, the pressures at the larger areas being larger, and those at the smaller areas smaller.

Precisely the same result will follow in the case of an enlargement followed by a contraction (see Plate IX. fig. 13)†.

This proposition can be illustrated by experiments performed with water.

Figs. 14, 15, show certain pipes, the one a contraction followed by an enlargement, and the other an enlargement followed by a contraction. At certain points in each pipe, vertical gauge-glasses are connected, the water-levels in which severally indicate the pressures in the pipe at the points of attachment.

In fig. 14 the sectional areas at E and P are equal to one another. Those at C and K are likewise equal to one another, but are smaller than those at E and P. The area at I is the smallest of all. Now, if the water were a perfect fluid, the pressures P Q and E D would be equal, and would be greater than C H and K N. C H and K N would also be equal to one another, and would be themselves greater than I J.

The results shown in fig. 15 are similar in kind, equal pressures corresponding to equal areas.

As water is not a perfect fluid, some of the pressure at each successive point is lost in friction; and this growing defect in pressure is indicated in the successive gauge-glasses in the manner shown in figs. 16, 17.

As the pressure of the perfect fluid in the pipe at any point depends upon the sectional area at that point, it follows that the amounts of the pressures are independent of the distance, as measured along the pipe, in which the area of the pipe alters; so that if in the pipe shown in Plate IX. fig. 18 the areas at all the points marked A are equal, if also the areas at all the points marked B are equal, and so also with those at C and D, then the pressures at all the points A will be the same, the pressures at all the points B will be the same, and so with those at C and D.

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* See Appendix, Note B.

† In a perfect fluid, we may say, in a sense, that the *vis viva* of each particle remains constant. If the particle is stationary, the *vis viva* is entirely represented by the pressure; if it be under no pressure, the *vis viva* is entirely represented by the velocity; if it be moving at some intermediate velocity, the *vis viva* is partly represented by the pressure and partly by the velocity.

Since, then, the pressure at each point depends on the sectional area at that point and on that only, it is easy to see that the variations in pressure due to the flow, are not such as can cause any total endways force on the pipe, provided its sectional area at each end is the same.

Take the pipe shown in fig. 19. The conical portion of pipe AB presents the same area of surface effective for endways pressure as does the conical portion HI, only in opposite directions. They are both subject to the same pressure, being that appropriate to their effective mean diameter J. Consequently the endways pressures on these portions are equal and opposite and neutralize one another. Precisely in the same way it may be seen that the endways pressures on B C, C D, D E exactly counteract those on G H, F G, E F; and in precisely the same way it may be shown that in any combination whatever of enlargements and contractions, provided the sectional area and direction of the pipe at the two ends are the same, the total endways effect impressed on the pipe by the fluid flowing through it must be *nil.*

In the experiment I am about to show you, the several propositions which I have been elucidating will be seen to be verified step by step, if due allowance be made for the effect of friction.

A cistern (see Plate X. fig. 20), in which a definite head of water is maintained, discharges itself through a continuous series of pipes, which, in their local changes of diameter, exhibit the several characteristic features which have been under consideration.

From *a* to *c* at the outlet end, we have a contraction followed by an enlargement; from *e* to *g* the diameter is uniform; from *h* to *l* we have an enlargement followed by a contraction. At the various critical features are fitted gauge-glasses such as have been described, so that the level at which the water stands in each indicates the pressure in the pipe at the point of attachment.

The series of pipes is laid out on an inclination which represents the mean resistance due to friction, or the "head" lost by friction, between the cistern and the outlet—in other words, the hydraulic mean gradient.

The mean diameter of the contracted part between *a* and *c* has been so determined by well-known hydraulic rules, that when it is compared with the adjoining parallel pipe, the hydraulic gradient shall be the same in each.

You observe that while the levels at which the water stands in the several gauge-glasses, correspond from end to end with the gradient from the head in the cistern to the head at the outlet, when examined in detail they verify throughout the propositions I have been establishing.

For if for the moment we regard the gradient as virtually level, the depressions of the several columns below it due to varying velocity of flow should be inversely as the fourth powers of the several diameters; but the local frictional gradient should be is inversely as the fifth power of the diameter, and thus steepest where the diameter is smallest. And, broadly speaking, the results plainly conform to these rules. As a quantitative verification I point out that by careful calculation the mean diameter, and therefore the gradient from a' to c', is the same as that for the parallel pipe from e' to g'; and the result agrees exactly with the calculation.

In dealing with pipes of varying sectional area I have hitherto treated only of the modifications caused in the forward motion of the particles of fluid; for I have limited the argument to cases where the alteration in sectional area of the pipe is so gradual that, practically, the only alteration in the motion of the particles is that in their forward velocity; but I have previously shown that tortuosity in a pipe of uniform diameter does not introduce endways pressure, provided the initial and terminal directions are the same; and it is easy to see that an elongated system of such gradually tapered pipes as we have been considering may be also tortuous without introducing endways pressure. Now tortuosity of flow is but another word for sideways deviation of flow.

This leads us up to the case of more sudden contractions or enlargements in pipes, where the particles next the sides of the pipes have to follow their surfaces and must therefore be moved rapidly sideways in their course.

We will, for simplicity, consider the case of a contraction (see Plate XI. fig. 21), and one in which the pipe resumes the same diameter beyond the contraction.

The particles along the central line pursue a straight course, and are subject only to the changes of pressure necessary to induce the changes of velocity.

To consider the behaviour of the other particles, let us assume that we insert a number of perfectly thin partitions (see fig. 22), which we lay in such a manner that they exactly follow the paths of the particles of fluid at each point, so as not in any way to affect their motion; these partitions are quite imaginary, and merely assist us in looking upon the entire fluid in question as divided into a number of small streams. These streams are generally curvilinear, and vary in sectional area; and at the point beyond the contraction where the pipe resumes its former sectional area, we shall naturally find these minor streams occupying the same sectional area as before, and moving with the same velocity as before.

Now each of these small streams is exactly represented by a stream of fluid flowing within a pipe, that pipe being curvilinear and gradually varying in sectional area, and its two ends being of the same sectional area and in the same straight line. We have seen that in the case of such a stream the sum total of all the forces due to its motion has no resultant longitudinally; and this will be equally the case, whether the envelope of the stream be an actual pipe or the mutual pressure of adjacent streams; this envelope will not be moved endways by the flow of the fluid. What is true of each stream is true of all put together; and thus it follows that the whole body of fluid which these separate streams constitute, does not exert any endways force; or, in other words, there will be equilibrium of fluid forces throughout the passage of the fluid through a local contraction in a pipe, such as we have been considering. The same line of argument evidently holds good in the case of an enlargement, where the pipe beyond the enlargement regains the same diameter as before.

In illustration of the conclusions which have been thus far established, if we had a perfect fluid with which to try the experiment, we might exhibit a very instructive and striking result.

Assume a stream of perfect fluid flowing through a pipe of very large diameter, A B C, with a contraction in it, at B, as shown in fig. 23, and that the equal pressures at A and C on either side of the contraction are indicated by the head of fluid in pressure-gauges A D, C E—the pressure at B, which will be less, being represented by the height B F. Now, the condition of the pipe at A will be just the same if we suppose the pipe supplied from a large cistern G, as shown in fig. 24; and the appropriate pressure at A will be maintained if the fluid stands in the cistern G at a height H, equal to the head A D in the pressure-gauge. So, again, the condition of the pipe at C will be the same if the pipe discharges into a cistern, I; and the appropriate pressure at C will be maintained, and can only be maintained, if the water in the cistern stands at a height J, equal to the head C E in the pressure-gauge, which is, in fact, the same level as H in the cistern G; so that if we once establish the motion through the pipe A B C, and maintain the supply of fluid, we shall have the fluid running rapidly, and continuing to run with unabated rapidity, from one cistern into another, though both are at the same head.

If we take such a condition of things that the pressure at B is zero, or, in other words, if the velocity at B is that due to the head A D, then we might cut the pipe at B and separate the two cisterns, and we should find the fluid issuing at B in a jet, and re-entering the pipe again at K, and rising as before in the cistern I to the same level with a perpetual flow.

The experiment here suggested is, if rightly understood, only a specialized instance of the properties of what in the previous experiment was termed a contraction followed by an enlargement; it is, in fact, as if in that experiment the diameter of the contracted part had been so far reduced that the pressure within it would have sunk apparently to zero—that is to say, in reality, to the pressure of the atmosphere; in that case, of course, the pipe which enclosed that portion of the stream would have become simply an inert envelope, and might have been removed without affecting the dynamic properties of the stream. Theoretically, indeed, with the frictionless fluid the contraction of jet might be carried so far as not merely to obliterate all positive pressure, but to produce a negative pressure equal to that of the atmosphere. For, in fact, the conditions thus brought into operation would be in effect identical with those which would exist if the experiment were performed *in vacuo*, and the head in cistern and at the outlet were both increased by 34 feet; but the theoretical possibility thus indicated is greatly curtailed by friction; and the illustrative experiment I am about to exhibit deals only with the case in which the pressure at the contraction is reduced apparently to zero, or in reality, as I have said, to that of the atmosphere.

In the apparatus as here arranged (see Plate XI. fig. 25), consisting of the discharging and the recipient cistern, with the intervening jet-orifice and recipient-orifice, the overflow of the recipient cistern is at 18 inches above the centre of the orifices.

As I continue to fill the discharge cistern, you observe the jet shoots across the open space between the orifices, and the water-level continues to rise in the recipient cistern; and so long as the head in the former is maintained at a moderate height above that in the latter, the whole of the stream enters the recipient-orifice, and there is no waste except the small sprinkling which is occasioned by inexactness of aim, and by the want of exact circularity in the orifices.

When the head in the recipient has reached the overflow, and thus remains at a steady height of 18 inches above the orifices, the virtually complete reception is insured by maintaining a head of 20½ inches in the discharging cistern, or an excess of head of 2½ inches on the discharge side; and this excess, in effect, represents the energy wasted in friction.

You observe that as I diminish the supply of water and allow the excess of head in the discharger to become reduced, a steadily increasing waste becomes established between the orifices; and it is interesting to trace exactly the manner in which the friction operates to produce this result.

If the conoids of discharge and reception are tolerably short as they are here, it is the outer annuli or envelopes of the stream which are in the first instance affected, that is to say retarded, by friction; and the escape or waste between the orifices implies that this surface-retardation has reduced the velocity of those envelopes below that due to the head in the recipient; thus an annular counter-current is able to establish itself, and in fact constitutes a counter discharge from the recipient.

As the head in the discharger is more and more reduced, the diminishing velocity of the central inflow into the recipient offers less and less frictional resistance to the annular counter-current which envelops it, and the waste continually increases; it is probable, however, that to the last the velocity of the central zones of the jet remains equal to that due to the head in the discharger; and hence you will observe that unless this is reduced below the level of the overflow, the head in the recipient is fully maintained to that level, though the whole quantity discharged is wasted between the orifices.

When the supply is altogether cut off, both cisterns simultaneously empty themselves, the two jets meeting between the orifices and becoming spread into a beautiful plane disk or film of water at right angles to the line of discharge; but you will notice that from some inequality in the commencement of the action, and to some extent probably from a quasi-instability in the equilibrium of the double discharge, one of the jets will presently for a moment get the better of the other and drive it back so as almost to arrest its flow, and thus for the moment arrest also the waste of head on that side; but the momentary excess of head thus occasioned, almost instantly asserts its superiority, producing a jet of superior force, and thus driving back for a moment the opponent by which it had just before been mastered. Thus a curious oscillation of discharge ensues, which is to a large extent a true dynamic phenomenon somewhat analogous to that which becomes established in an inverted siphon partly filled with water, if for a moment the head is increased in one of the legs; the reaction which in the siphon is furnished by the other leg, beyond the bend, is, in the case before you, furnished by the dynamic reaction of the jets; but the circumstances here involve an instability which does not exist there, so that the small initial disturbance presently magnifies itself into one of considerably greater range.

This curious corollary phenomenon of the alternated retardation of discharge, though not strictly relevant to the main object of the experiment, is nevertheless highly interesting in itself, and tends to enlarge our apprehension of some of the characteristic features of fluid dynamics.

In this treatment of the propositions concerning the flow of fluid through pipes, I have at length laid the necessary foundation for the treatment of the case of the flow of an infinite ocean past a submerged body. I have shown these propositions to be based on principles which are undeniable, and the conclusions from which, when they seemed in any way startling or paradoxical, you have seen confirmed by actual experiment.

I have dealt with the case of a single stream of uniform sectional area (and therefore of uniform velocity of flow) enclosed in a pipe of any path whatever; I have dealt with the case of a single stream of very gradually varying sectional area and velocity of flow; and I have dealt with the case of a combination (or faggot, as it were) of such streams, each to some extent curved and to some extent varying in sectional area, together composing the whole content of a pipe or passage having enlargements or contractions in its course; and in all these cases I showed that, provided the streams or pipe-contents finally return to their original path and their original velocity of flow, they administer no total endways force to the pipe or channel which causes their deviations.

I am now going to deal with a similar combination of such streams, which, when taken together, similarly constitute an infinitely extended ocean, flowing steadily past a stationary submerged body; and here also I shall show that the combination of curved streams surrounding the body, which together constitute the ocean flowing past it, return finally to their original direction and velocity, and cannot administer to the body any endways force.

The argument in this case is, in reality, precisely the same as that in the case of the contractions and enlargements in pipes which I have already dealt with; for, in fact, the flow of the ocean past the stationary submerged body is only a more general case of the flow of fluid through a contracted pipe; but, though the cases are really the same, there is considerable difference in their appearance; and therefore I will proceed to point out how the arguments I have already used apply equally to this case.

Every particle of the fluid composing the ocean that passes the body must undoubtedly follow some path or other, though we may not be able to find out what path; and every particle so passing is preceded and followed by a continuous stream of particles all following the same path, whatever that may be. We may, then, in imagination, divide the ocean into streams of any size and of any cross-section we please, provided they fit into one another, so as to occupy the whole space, and provided the boundaries which separate the streams exactly follow the natural courses of the particles.

I before suggested a similar conception of the constitution of the ocean flowing past the stationary body, and there pointed out that the streams forming this system must not only be curved in order to get out of the way of the body, but might each require to have to some extent a different sectional area, and therefore a different velocity of flow at different points of their course. If we trace the streams to a sufficient distance ahead of the body, we shall there find the ocean flowing steadily on, completely undisturbed by, and as we may say ignorant of, the existence of the body which it will ultimately have to pass. There, all the streams must have the same direction, the same velocity of flow, and the same pressure. Again, if we pursue their course backwards to a sufficient distance behind the body, we shall find them all again flowing in their original direction; they will also have all resumed their original velocity; for otherwise, since the velocity of the ocean as a whole cannot have changed, we should have a number of parallel streams having different velocities and therefore different pressures side by side with one another, which is an impossible state of things*.

* In an imperfect fluid it is possible to have parallel streams having different velocities side by side with one another, because, in an imperfect fluid, change of velocity may have been communicated by friction, and therefore does not imply difference of pressure.

Although, in order to get past the body, these streams follow some courses or other, various both in direction and velocity, into which courses they settle themselves in virtue of the various reactions which they exert upon one another and upon the surface of the body, yet ultimately, and through the operation of the same causes, they settle themselves into their original direction and original velocity. Now the sole cause of the original departure of each and all of these streams from, and their ultimate return to, their original direction and velocity, is the submerged stationary body; consequently the body must receive the sum total of the forces necessary to thus affect them. Conversely this sum total of force is the only force which the passage of the fluid is capable of administering to the body. But we know that to cause a single stream, and therefore also to cause any combination or system of streams, to follow any courses changing at various points both in direction and velocity, requires the application of forces the sum total of which in a longitudinal direction is *zero*, provided that the end of each stream has the same direction and velocity as its beginning. Therefore the sum total of forces (in other words the only force) brought to bear upon the body by the motion of the fluid in the direction of its flow is *zero**.

I have now shown how it is that an infinite ocean of perfect fluid flowing past a stationary body cannot administer to it any endways force, whatever be the nature of the consequent deviations of the streams of fluid. The question, what will be in any given case the precise configuration of those deviations, is irrelevant to the proof I have given of this proposition. Nevertheless it is interesting to know something, at least, of the general character which these deviations, or "stream-lines," assume in simple cases; therefore I have exhibited some in Plate XI. figs. 26, 27, which are drawn according to the method explained by the late Professor Rankine.

The longitudinal lines represent paths along which particles flow; they may therefore be regarded as boundaries of the streams into which we imagined the ocean to be divided.

We see that, as the streams approach the body, their first act is to broaden, and consequently to lose velocity, and therefore, as we know, to increase in quasi-hydrostatic pressure. Presently they again begin to narrow, and therefore quicken, and diminish in pressure, until they pass the middle of the body, by which time they have become narrower than in their original undisturbed condition, and consequently have a greater velocity and less pressure than the undisturbed fluid. After passing the middle they broaden again until they become broader than in their original condition, and therefore have less velocity and greater pressure than the undisturbed fluid. Finally, as they recede from the body they narrow again, until they ultimately resume their original dimension, velocity, and pressure.

Thus, taking the pressure of the surrounding undisturbed fluid as a standard, we have an excess of pressure at both the head and stern ends of the body, and a defect of pressure along the middle.

We proved just now that, taken as a whole, the fluid pressures could exert no endways push upon the stationary body. We now see something of the way in which the separate pressures act, and that they do not, as seems at first sight natural to expect, tend all in the direction in which the fluid is flowing; on the contrary, pressure is opposed to pressure, and suction to suction, and the forces neutralize one another and come to nothing; and thus it is that an ocean of perfect fluid flowing at steady speed past a stationary submerged body does not tend to push it in the direction of the flow. This being so, a submerged body travelling at steady speed through a stationary ocean of perfect fluid will experience no resistance.

We will now consider what will be the result of substituting an ocean of water for the ocean of perfect fluid.

The difference between the behaviour of water and that of the theoretically perfect fluid is twofold, as follows:—

First. The particles of water, unlike those of a perfect fluid, exert a drag or frictional resistance upon the surface of the body as they glide along it. This action is commonly termed surface-friction, or skin-friction; and it is so well known a cause of resistance that I need not say any thing further on this point, except this, that it constitutes almost the whole of the resistance experienced by bodies of tolerably easy shape travelling under water at any reasonable speed.

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* See Appendix, Note C.

Secondly. The mutual frictional resistance experienced by the particles of water in moving past one another, combined with the almost imperceptible degree of viscosity which water possesses, somewhat hinders the necessary stream-line motions, alters their nice adjustment of pressures and velocities, and thus defeats the balance of stream-line forces and induces resistance. This action, however, is imperceptible in forms of fairly easy shape. On the other hand, angular or very blunt features entail considerable resistance from this cause, because the stream-line distortions are in such cases abrupt, and degenerate into eddies, thus causing great differences of velocity between adjacent particles of water, and great consequent friction between them. "Dead water," in the wake of a ship with a full run, is an instance of this detrimental action.

So far we have dealt with submerged bodies only; we will now take the case of a ship travelling at the surface of a perfect fluid. But first, let us suppose the surface to be covered with a sheet of rigid ice, and the ship cut off level with her water-line, so as to travel beneath the ice, floating, however, exactly in the same position as before (see Plate XI. fig. 28). As the ship travels along, the stream-line motions will be the same as for a submerged body, of which the ship may be regarded as the lower half; and the ship will move without resistance, except that due to the two causes I have just spoken of, namely surface-friction and mutual friction of the particles. The stream-line motions being the same in character as those we have been considering, we shall still have at each end an excess of pressure which will tend to force up the sheet of ice, and along the side we shall have defect of pressure tending to suck down the sheet of ice. If, now, we remove the ice, the fluid will obviously rise in level at each end, so that excess of hydrostatic head may afford the necessary reaction against the excess of pressure; and the fluid will sink by the sides, so that defect of hydrostatic head may afford reaction against the defect of pressure; and the same actions and reactions will happen in the imperfect fluid, water, making only the same allowance for the modification of velocities and pressures by friction as were shown to be necessary in treating of wholly submerged bodies.

The hills and valleys thus formed in the water are, in a sense, waves; and, though originating in the stream-line forces of the body, yet when originated, they come under the dominion of the ordinary laws of wave-motion, and, to a large extent, behave as independent waves.

The consequences which result from this necessity are most intricate; but the final upshot of all the different actions which take place is plainly this—that the ship in its passage along the surface of the water has to be continually supplying the waste of an attendant system of waves, which, from the nature of their constitution as independent waves, are continually diffusing and transmitting themselves into the surrounding water, or, where they form what is called broken water, crumbling away into froth. Now waves represent energy, or work done; and therefore all the energy represented by the waves wasted from the system attending the ship, is so much work done by the propellers or tow-ropes which are urging the ship. So much wave-energy wasted per mile of travel, is so much work done per mile; and so much work done per mile is so much resistance, and this cause of resistance at least would operate with full effect even in a perfect fluid.

The actions involved in this cause of resistance, which is sometimes termed "Wave-Genesis," are so complicated that no extensive theoretical treatment of the subject can be usefully attempted. All that can be known about the subject must, for the present I believe, be sought by direct experiment.

Having thus briefly described the several elements of a ship's resistance, I will proceed to draw your attention more particularly to certain resulting considerations of practical importance. Do not, however, suppose that I shall venture on dictating to shipbuilders what sort of ships they ought to build: I have so little experience of the practical requirements of ship-owners, that it would be presumptuous in me to do so; and I could not venture to condemn any feature in a ship as a mistake, when, for all I know, it may be justified by some practical object of which I am ignorant. For these reasons, if I imply that some particular element of form is better than some other, it will be with the simple object of illustrating the application of principles, by following which it would be possible to design a ship of given displacement to go at given speed, with minimum resistance, in smooth water—in fact, to make the best performance in a "measured mile" trial.

I have pointed out that the causes of resistance to the motion of a ship through the water are:—first, surface-friction; secondly, mutual friction of the particles of water (and this is only practically felt when there are features sufficiently abrupt to cause eddies); and thirdly, wave-genesis. I have also shown that these are the *only* causes of resistance. I have shown that a submerged body, such as a fish, or torpedo, travelling in a perfect fluid, would experience no resistance at all; that in water it experiences practically no resistance but that due to surface-friction and the action of eddies; and that a ship at the surface experiences no resistance in addition to that due to these two causes, except that due to the waves she makes. I have done my best to make this clear; but there is an idea that there exists a form of resistance, a something expressed by the term "direct head-resistance," which is independent of the above-mentioned causes. This idea is so largely prevalent, of such long standing, and at first sight so plausible, that I am anxious not to leave any misunderstanding on the point.

Lest, then, I should not have made my meaning sufficiently clear, I say distinctly, that the notion of head-resistance, in any ordinary sense of the word, or the notion of any opposing force due to the inertia of the water on the area of the ship's way, a force acting upon and measured by the area of midship section, is, from beginning to end, an entire delusion. No such force acts at all, or can act, as throughout the greater part of this address I have been endeavouring to explain. No doubt, if two ships are of precisely similar design, the area of midship section may be used as a measure of the resistance, because it is a measure of the size of the ship; and if the ships were similar in every respect, so also would the length of the bowsprit, or the height of the mast, be a measure of resistance, and for just the same reason. But it is an utter mistake to suppose that any part of a ship's resistance is a direct effect of the inertia of the water which has to be displaced from the area of the ship's way. Indirectly the inertia causes resistance to a ship at the surface, because the pressures due to it make waves. But to a submerged body, or to the submerged portion of a ship travelling beneath rigid ice, no resistance whatever will be caused by the inertia of the water which is pushed aside. And this means that, if we compare two such submerged bodies, or two such submerged portions of ships travelling beneath the ice, as long as they are both of sufficiently easy shape not to cause eddies, the one which will make the least resistance is the one which has the least skin surface, though it have twice or thrice the area of midship section of the other.

The resistance of a ship, then, practically consists of three items—namely, surface-friction, eddy-resistance, and wave-resistance.

Of these the first-named is, at least in the case of large ships, much the largest item. In the 'Greyhound,' a bluff ship of 1100 tons, only 170 feet long, and having a thick stem and sternposts, thus making considerable eddy-resistance, and at 10 knots visibly making large waves, the surface-friction was 58 per cent. of the whole resistance at that speed; and there can be no doubt that with the long iron ships now built, it must be a far greater proportion than that. Moreover the 'Greyhound' was a coppered ship; and most of the work of our iron ships has to be done when they are rather foul, which necessarily increases the surface-friction item.

The second item of resistance, namely the formation of eddies, is, I believe, imperceptible in ships as finely formed as most modern iron steamships. Thick square-shaped stems and sternposts are the most fruitful source of this kind of resistance.

The third item is wave-resistance. On this point, as we have seen, the stream-line theory rather suggests tendencies, than supplies quantitative results, because, though it indicates the nature of the forces in which the waves originate, the laws of such wave-combinations are so very intricate, that they do not enable us to predict what waves will actually be formed under any given conditions.

There are, however, some rules, I will not call them principles, which have to some extent been confirmed by experiment. At a speed dependent on her length and form, a ship makes a very large wave-resistance. At a speed not much lower than this, the wave-resistance is considerably less, and at low speeds it is insignificant. Lengthening the entrance and run of a ship tends to decrease the wave-resistance; and it is better to have no parallel middle body, but to devote the entire length of the ship to the entrance and run, though in this case it be necessary to increase the midship section in order to get the same displacement in a given length.

With a ship thus formed, with fair water-lines from end to end, the speed at which wave-resistance is accumulating most rapidly, is the speed of an ocean wave the length of which, from crest to crest, is about that of the ship from end to end.

I have said we may practically dismiss the item of eddy-resistance. The problem, then, to be solved in designing a ship of any given size, to go at a given speed with the least resistance, is to so form and proportion the ship that at the given speed the two main causes of resistance, namely surface-friction and wave-resistance, when added together, may be a minimum.

In order to reduce wave-resistance we should make the ship very long. On the other hand, to reduce the surface-friction we should make her comparatively short, so as to diminish the surface of wetted skin. Thus, as commonly happens in such problems, we are endeavouring to reconcile conflicting methods of improvement; and to work out the problem in any given case, we require to know actual quantities. We have sufficient general data from which the skin-resistance can be determined by simple calculation; but the data for determining wave-resistance must be obtained by direct experiments upon different forms to ascertain its value for each form. Such experiments should be directed to determine the wave-resistance of all varieties of water-line, cross section, and proportion of length, breadth, and depth, so as to give the comparative results of different forms as well as the absolute result for each.

An exhaustive series of such experiments could not be tried with full-sized ships; but I trust that the experiments I am now carrying out with models, for the Admiralty, are gradually accumulating the data required on this branch of the subject.

I wish in conclusion to insist again, with the greatest urgency, on the hopeless futility of any attempt to theorize on goodness of form in ships, except under the strong and entirely new light which the doctrine of stream-lines throws on it.

It is, I repeat, a simple fact that the whole framework of thought by which the search for improved forms is commonly directed, consists of ideas which, if the doctrine of stream-lines is true, are absolutely delusive and misleading. And real improvements are not seldom attributed to the guidance of those very ideas which I am characterizing as delusive, while in reality they are the fruit of painstaking, but incorrectly rationalized, experience.

I am but insisting on views which the highest mathematicians of the day have established irrefutably; and my work has been to appreciate and adapt these views when presented to me*.

No one is more alive than myself to the plausibility of the unsound views against which I am contending; but it is for the very reason that they are so plausible that it is necessary to protest against them so earnestly; and I hope that in protesting thus, I shall not be regarded as dogmatic.

In truth, it is a protest of scepticism, not of dogmatism; for I do not profess to direct any one how to find his way straight to the form of least resistance. For the present we can but feel our way cautiously towards it by careful trials, using only the improved ideas which the stream-line theory supplies, as safeguards against attributing this or that result to irrelevant or, rather, non-existing causes.

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* I cannot pretend to frame a list of the many eminent mathematicians who originated or perfected the stream-line theory; but I must name, from amongst them, Professor Rankine, Sir William Thomson, and Professor Stokes, in order to express my personal indebtedness to them for information and explanations, to which chiefly (however imperfectly utilized) I owe such elementary knowledge of the subject as alone I possess.

APPENDIX.

NOTE A.

The proposition, that the flow of fluid through a tortuous pipe having its ends in the same straight line does not tend to push the pipe endways, can be treated in several ways, of which only one is given in the accompanying address; but it may be interesting to some readers to trace some of the other ways of viewing the question.

First let us take the case of a right-angled bend in a pipe (that is to say, where the direction of a pipe is altered through a right angle by a curve of greater or less radius; a bend of this sort is shown in Plate XII. fig. 29), and assume that the fluid in it at A is flowing from A towards C. I propose at present to deal only with those forces or tendencies which act more or less powerfully in the direction of the original motion of the fluid, namely along the line AC.

I must here remind you that I am dealing with this matter entirely independently of hydrostatic pressure. Perhaps to some it will be difficult to disassociate the idea of hydrostatic pressure from a fluid in a pipe. This difficulty might be got over by assuming that the pipe is immersed in a fluid of the same density and head as the fluid within it. There will thus be hydrostatic equilibrium between the fluid within and without the pipe, the only difference being that the fluid inside the pipe is assumed to be in rapid motion, and thus subjects the pipe to any stresses properly incidental to that motion of the fluid within it.

The sole work that has to be done in the present case is that of deflecting the current of fluid to a course at right angles to its original course AC; and, regarding the forces employed in this work as resolvâble throughout into two sets of components, the one at right angles to the line AC, the other parallel to it, it is of the latter alone that account is to be taken. Manifestly the sum of these latter components is measured by the circumstance that it is precisely sufficient to entirely destroy the forward momentum of the fluid that flows along the pipe at A towards the bend. This force is administered to the fluid by the curved portion of the pipe at the bend DEF; and, as the pipe is assumed to be rigid, the work of arresting the forward velocity of the fluid throws a forward stress on the pipe in the line AC.

Let us now assume that to the right-angled bend, AB, we attach rigidly a second right-angled bend, BG, as shown in fig. 30, in such a manner that the termination of this second bend at G is parallel to the commencement of the first bend at A. Here I will again, for the present, deal only with the forces in a direction parallel to the line AC.

The fluid at B has no velocity in the direction of the line AC, and at G it has a velocity in that direction equal to the velocity which it had at A. To give it this velocity in a forward direction (I mean forward in its original direction of motion)—to establish this forward momentum, requires the application of a force in the direction HG; and this force is administered to the fluid by the curved portion of the pipe at the bend IJK; and as the pipe is assumed to be rigid, the duty of establishing the forward velocity of the fluid, throws a rearward stress on the pipe in the direction GH. Now as the forward momentum given to the fluid between B and G, in the line GH, is exactly the same as the momentum destroyed between A and B in the line AC, it follows that the rearward stress thrown on the pipe at the bend IJK is exactly equal to the forward stress thrown on the pipe at the bend DEF. Hence it will be seen that the forces acting on the rigid pipe AG, treated as a whole, balance each other, so far as relates to the forces in the line AC, the original line of motion of the fluid; that is to say, the forward stress acting on the pipe at the bend DEF is balanced by the equal rearward stress acting on the pipe at the bend IJK. These two of the forces acting on the pipe are shown by the arrows L and M, which, it must be remembered, are the only forces which act in a line parallel to AC.

It will have been seen that the measure of these forces is the amount of forward momentum of the fluid which is destroyed or created; and from this it will be inferred that the forces will be the same, no matter what is the radius of the curve of the pipe, inasmuch as the curvature of the pipe does not affect the amount of the forward momentum of the fluid that has to be destroyed or replaced.

Let us next take the case of a bend in a pipe that is not a right angle, as shown in Plate XII. fig. 31; and here, as before, I only propose to deal with the forces that come into play in the direction A C of the original motion of the fluid. Now in this case the forward motion of the fluid is not, as in the instance of the right-angled bend, entirely destroyed in its progress from A to B; only a portion of the motion is checked, and a portion of the momentum destroyed; and the magnitude of the force required to destroy the momentum is in proportion to the amount by which the forward velocity of the fluid in the line A C is destroyed. This force is administered to the fluid by the curved portion of the pipe at the bend D E F, and, as in the former case, exercises by reaction on the pipe a forward stress, which will be in proportion to the extent by which the forward motion of the fluid is checked by the divergence of the pipe from its original line.

Suppose to this bend we attach rigidly another bend B G of the same angle, as shown in fig. 32, so that the termination of this second bend at G is parallel to the commencement of the first bend at A. Here, in the portion of the pipe B G, that part of the forward velocity which was taken away has to be again given to the fluid; this requires force, which is administered to the fluid by the curved part I J K, of the pipe. There is thus thrown on the pipe a rearward stress represented by M. The force required in the bend between B and G to reinstate completely the forward velocity, is evidently the same in amount as the force required in the bend between A and B to destroy in part the forward velocity.

It follows, therefore, that the two stresses on the pipe, represented by the arrows L and M, which indicate the forces acting on the pipe, are equal and opposite to one another; and these are the only forces acting on the rigid pip in the line A C of the original motion of the fluid at A. It follows, therefore, that in the case of two right-angled bends rigidly attached, or in the case of two connected equal-angled bends of any other angle, the stresses brought on the pipe by the flow of the fluid will not tend to move the pipe bodily endways.

It will be seen also by this reasoning that the forces we have referred to do not depend on the curvature of the pipes, but are simply measured by the amount of the forward momentum of the fluid and the extent to which that momentum is modified in the total amount of deflection of the course of the fluid at the bend, or, in other words, by the angle of the bend. And from this reasoning it becomes apparent that by whatever bends or combinations of bends we divert the course of a stream of fluid in the pipe, provided the combination be such as to restore the stream to its original direction, the aggregate of the forces in one direction required to destroy forward momentum are necessarily balanced by equal forces in the opposite direction required to reinstate the former momentum.

It will be useful to consider more in detail the action of all the forces acting on a fluid in a bend of the pipe; and I will return to the case of a single right-angled bend, as shown in fig. 29. I before spoke merely of the forces acting parallel to the line AC, and said that the forward momentum of the fluid in that line had to be destroyed in its passage round the bend DEF, and that this must be effected by a force acting parallel to AC, which would by its reaction throw a forward stress on the pipe, tending to force it in the direction AC. But similarly velocity has to be given to the fluid in the direction NB; and to do this a force must be administered to the fluid which will cause a reaction on the pipe in the direction BN; and as the momentum to be established in the direction NB, has to be equal to that in the direction AC, which had to be destroyed, it follows that the forces of reaction upon the pipe in the directions AC and BN are equal. These forces can be met in two ways, either by securing the bent part of the pipe DEF so that it will in each part resist the stresses that come on it, or by letting the forces be resisted by the tensional strength of the straight parts of the pipe AD and BF, operating in the direction of their length; and in this case we see that the tension on AD must be equal to the force acting along AC, and the tension on BF must be equal to the equal force acting along BN, so that in fact the forces brought into play by the right-angled bend

produce a longitudinal tension on the pipe at either end of the bend equal to the force required to destroy the forward momentum of the fluid.

Proceeding to the case of the non-right-angled bend, as shown in fig. 31—in this case, as we have seen, a portion only of the forward momentum of the fluid in the line AC has to be destroyed, also a certain amount of sideways momentum has to be created in a direction which we may consider parallel to the line QP; and the composition of the remaining forward momentum in the line AC with the created sideways momentum in the line QP, results in the progress of the fluid along the path FB; this partial destruction of forward momentum and establishment of some sideways momentum are essential to the onward progress of the fluid along FB. The bend DEF will be subject to the reaction of the forces necessary to produce these changes; and either the bend may be locally secured, or the stress upon it may be met, as in the case of the right-angled bend we have just been considering, by a tensional drag on the pipe at either end of the bend. There is, however, this difference between the cases, that the force required to establish sideways momentum parallel to QP cannot be directly met by the reaction of tension along the line BF of the second part of the pipe; but this force may be met by the obliquely acting tension of the pipe BF combined with additional tension along the pipe AD. It is well known that in the case of a given force, such as that we are supposing parallel to PQ, resisted by two obliquely placed forces such as the tension along the lines DA and FB, the nearer the lines DA and FB are to one straight line, the greater must be the tension along those lines to balance a given force acting on the line PQ. Now the less the line FB diverges from the line AC, the less will be the sideways momentum parallel to QP that has to be imparted to the fluid; but at the same time and to precisely the same extent will the proportionate tension put upon the limbs DA and FB of the pipe be aggravated by the greater obliquity of their action. The sideways pull is greatest when the bend is a right angle; and then it amounts to a force that will take up or give out the entire momentum of the fluid, and it is supplied directly by the tension of the limb of the pipe at FB. If the bend is made less than a right angle, the less the bend is made, the less is the sideways pull, but the greater by the same degree is the disadvantage of the angle at which the tension on the pipe resists the pull; and it results from this that in the case of a bend other than a right angle, the tension on the pipe is the same as in the case of a right-angled bend. A geometrical proof of this is given in fig. 33. It is evident that the radius of curvature of the bend does not enter into this consideration, and that the forces acting are not affected by the rate of curvature of the pipe, the simple measure of the forces being the increase or decrease in the momentum of the fluid in each direction. It results from this that if a fluid be flowing along a pipe with a bend in it, no matter what may be the angle of the bend or the radius of its curvature, the reactions necessary to deflect the path of the fluid will be met by a tensional resistance along the pipe; and this tension is equal to the force that would be required to entirely destroy the momentum of the fluid.

If we now assume any number of bends, of any angle or curvature, to be connected together (see Plate IX. fig. 3), the equilibrium of each bend is satisfied by a longitudinal tension which is in every case the same; and this tension is therefore uniform throughout the pipe; for the tension at any intermediate point in a bend is clearly the same as at the ends of the bend, as we may suppose the bend to be divided at that point into two bends, and there joined together by an infinitely short piece of straight pipe.

If then the tortuous pipe I have above referred to has its ends at A and B parallel to one another, as shown in fig. 4, it is clear that the tensional forces at its ends balance one another, and the pipe, as a whole, does not tend to move endways.

NOTE B.

The law regulating these changes of pressure due to changes of velocity can be best understood by considering the case of a stream of perfect fluid flowing from a gradually tapeerd pipe or nozzle placed horizontally and connected with the bottom of a cistern, as shown in Plate XII. fig. 34. Let us suppose that at the points B and C the sectional areas of the pipe are severally twico and four times that at the point of exit A.

At the point of exit A the fluid is under no pressure whatever, since there is no reacting force to maintain any pressure; each particle of fluid in the issuing jet is rushing on on its own account, neither giving nor receiving pressure from its neighbours. We know, however, what force it has taken to give the velocity which the fluid has at the point of issue A, and we measure this force by the pressure, or head of fluid, lost. In the case we are considering, this head is represented by the height of the fluid in the cistern, or by the height AD.

Within the cistern, at the point E, on the same level as A the point of issue—at this point E within the cistern, we have the pressure due to the head of fluid equal to AD, but we have no velocity, at any rate the velocity is so small as to be inappreciable; and at the point of issue A we have no pressure at all, but we have what is termed the "velocity due to the head."

Let us suppose that at the points A, B, C, and E, gauge-glasses or stand-pipes are attached so that the fluid in each may rise to a height corresponding with the pressure within the pipe or nozzle at the point of attachment.

The gauge-glass attached at A will show no pressure, thus indicating that the entire head AD has been expended in producing the velocity at the point A.

At the point B, as the sectional area is twice, the velocity is one half that at A. Now the head required to produce velocity varies as the square of the velocity to be produced; in other words, to produce half the velocity requires one quarter of the head; thus of the whole head AD available, one quarter only, or GD, has been absorbed in developing the velocity at B, and the remainder of the pressure, which will be represented by the head BG, will be sensible at the point B, and will be exhibited in the gauge-glass attached at that point.

Again, as the pipe at C is four times the area that it is at A, it follows that, of the whole head AD, one sixteenth part only, or HD, has been absorbed in developing the velocity at C, and the remainder of the pressure, which will be represented by the head CH, will be sensible at the point C, and will be exhibited in the gauge-glass attached at that point.

In the case I have chosen for illustration the small end, A, of the nozzle, is open and discharging freely, and the pressure at that point is therefore *nil.* But the absolute differences of pressure at each point of the pipe or nozzle will be precisely the same (as long as the same quantity of fluid is flowing through it per second), however great be the absolute pressures throughout.

Thus, suppose that from the end of the nozzle at A a pipe of the same diameter, and of uniform diameter throughout its length, is curved upwards so that the end of it, I, is two feet higher than A, as shown in Plate XII. fig. 35, if the level of the cistern is also raised two feet, namely to the level marked J, instead of D, we shall have the same delivery of fluid as before; and the differences between the pressures at each point will be the same as before.

If we add 50 feet instead of 2 feet to the head in the cistern; and raise I to 50 feet, instead of 2 feet above the nozzle, the differences of head or pressure will still be the same, the head at A being 50 feet, that at B being BG+50 feet, that at C, CH+50 feet, and that at E (the cistern-level) ED+50 feet.

To put the case into actual figures, suppose the sectional area at A to be 1 square inch; that at B, 2 square inches; and that at C, 4 square inches; and suppose that the fluid is passing through the nozzle at the rate of one ninth of a cubic foot per second; we shall have a velocity at A of 16 feet per second—to generate which would require a difference of pressure between E and A equivalent to 4 feet of vertical head. The velocity at B will be 8 feet per second, which would require a difference between E and B equivalent to 1 foot of head. That at C will be 4 feet per second, and will require a difference of pressure equivalent to 3 inches of head. If the pressure at A be zero, the pressures at B, C, and E will be 3 feet, 3 feet 9 inches, and 4 feet respectively. If the pressure at A be 1 foot, the pressures at B, C, and E will be 4 feet, 4 feet 9 inches, and 5 feet respectively; and if the pressure at A be 1000 feet, the pressures at B, C, and E will be 1003 feet, 1003 feet 9 inches, and 1004 feet respectively, always supposing the quantity of fluid passing per second to be the same. If the quantity be different, the absolute differences of pressure will be different, but will be relatively the same. If, for instance, the quantity flowing per second be doubled, the velocity at each point will be doubled, and the differences of pressure quadrupled; so that if the pressure at A were again 1000 feet, those at B, C, and E would be 1012, 1015, and 1016 feet respectively.

To sum up—the differences of hydrostatic pressure at different points vary as *the differences of the squares of the velocities* at those points.

NOTE C.

Here again the argument given in the text suggests certain other lines of argument which some persons may feel interested in following out.

Suppose each and every one of the streams into which we have subdivided the ocean to be enclosed in an imaginary rigid pipe made exactly to fit it throughout, the skin of each pipe having no thickness whatever. The innermost skin of the innermost layer of pipes (I mean that layer which is in contact with the side of the body), the innermost skin, I say, of this layer is practically neither more nor less than the skin or surface of the body. The other parts of the skins of this layer, and all the skins of all the other pipes, simply separate fluid from fluid, which fluid, *ex hypothesi*, would be flowing exactly as it does flow if the skins of the pipes were not there; so that, in fact, if the skins were perforated, the fluid would nowhere tend to flow through the holes. Under these circumstances there clearly cannot be any force brought to bear in any direction by the flow of the fluid, on any of the skins of any of the pipes except the innermost skin of the innermost layer. Now, remembering that we are dealing with a perfect fluid which causes no surface-friction, we know that the fluid flowing through this system of pipes administers no total endways force to it. But it produces, as we have just seen, no force whatever upon any of the skins which separate fluid from fluid; consequently, if these are removed altogether, the force administered to the remainder of the system, will be the same as is administered to the whole system—namely, no total endways force whatever. But what is the remainder of the system? Simply the surface of the body, which is formed, as I have already said, by the innermost skins of the innermost layer of pipes. Therefore no total endways force is administered to the surface of the body by the flow of the fluid.

Lastly, let us recur for an instant to the case of fluid flowing through the single flexible pipe. Here it was proved that the flow of the fluid through it, if it was anchored at the two ends, did not tend to displace any part of it, because the centrifugal forces, produced by the flow of the fluid, and which must act exactly at right angles, or normally, as it is called, to the line of pipe at each point, are exactly counterbalanced by a uniform tension throughout the length of the pipe. If the flexible pipe has variations in its diameter, the differences of quasi-hydrostatic head appropriate to those variations are also normal to the surfaces of the pipe, being simply bursting-pressures. If, however, these normal forces were directly counterbalanced by equal and opposite and normal external forces or supports, it is obvious that this tension would be entirely relieved. Now, if we suppose the system of pipes which we have several times already imagined to surround the submerged body, to be flexible pipes, (instead of rigid pipes, as we have before imagined them), the counterbalancing, or normal, external forces which exactly relieve the tension are supplied to each pipe by its neighbour, except in the case of the innermost skin of the innermost layer of pipes, since this innermost skin has no neighbour. In this instance the counterbalancing, normal, external forces are supplied by the rigidity of the surface of the body. Now we know that, since the tensional forces produced by the flow of fluid through a flexible pipe, whether of uniform or varying sectional area, have no sum total of endways force, the counterbalancing forces which exactly relieve this tension must also have no total endways force; and since the counterbalancing forces acting throughout the whole system have thus no sum total of endways force, it can be proved, as before in the case of the similar system of rigid pipes, that if we remove the whole of the skins or sides of pipes, which separate fluid from fluid and which are all therefore necessarily in perfect equilibrium, the forces acting on the remainder, namely on those skins which are in contact with the surface of the body, forces which therefore may be considered as acting simply upon the body, must also have no endways sum total.

On the Drainage of the City and County of Bristol. By FREDERICK ASHMEAD, *M. Inst. C.E., Engineer and Surveyor to the Sanitary Authority.*

The borough of Bristol extends over an area of 4687 acres, or nearly 8 square miles, containing a population at the last Census in 1871 of 182,524, with an estimated population of 196,186 in 1875, and about 120 miles of streets and roads. The rateable value in 1875 was £739,045. Number of houses in 1871, 27,536.

About the year 1803, the Bristol Dock Company was formed for the purpose of floating portions of the rivers Avon and Frome under the direction of Mr. William Jessop, C.E., and on April 30, 1809, the works were set in operation. From that date down to 1825 frequent complaints were made of the offensive state of the Frome part of the Harbour, and the Dock Company constructed the Culvert known as Mylnes Culvert in addition to the Bread-Street Culvert previously constructed. By means of these culverts a large quantity of sewage was removed from the floating harbour, and discharged into the tidal river.

These culverts, with the existing sewers in the old city and the new sewers constructed by the late Surveyor to the Commissioners, Mr. John Armstrong, Assoc.Inst.C.E., making a length of about 41 miles, completed the drainage of the old city at the time of the adoption of "The Public Health Act" in 1851, at which time the outlying districts of Clifton, Westbury, St. Philip and Jacob, the District Parishes, and Bedminster were placed under one government, viz. the Corporation of the City and County of Bristol, acting as the Local Board of Health, since which time the management and control of the sewers of the whole district has been entrusted to a Committee of the Council elected annually.

One of the first acts of this Committee was to ascertain the state of the drainage of the whole borough with a view of improving the same; and it was decided to proceed with the drainage gradually and in districts, as the best and cheapest manner, this course being almost a necessity in consequence of the peculiarly isolated position of parts of the borough, by reason of the rivers Avon and Frome (floating harbour, locks, tidal basins, and other works) naturally dividing the whole borough into districts—the levels and dimensions of the sewers being so designed and arranged as to form one continuous scheme, to be eventually united so as to discharge the sewage of the whole borough at two points, one on each side of the river, for deodorization or for continuing the same to the mouth of the river Avon to be hereafter determined; and for drainage purposes the borough has been divided into six districts, viz. 1st, *Clifton High Level*; 2nd, *Bedminster*; 3rd, *Clifton Low Level*; 4th, *Saint Philip's*; 5th, *The Frome Intercepting*; 6th, *The Avon Intercepting*.

1st. *Clifton High-Level District.*—Clifton has been divided into two districts, viz. the High- and the Low-Level districts; and the first undertaken was the High-Level district. It includes the whole of the higher parts of Clifton, and parts of Westbury and Cotham, and is drained by means of a main sewer commencing in Hampton Road, passing under White Ladies Road, along Alma Road under the College grounds, and the Clifton Down Road, passing down the new zigzag to the river Avon. Main branch sewers are also constructed along the several main roads of the district.

2nd. *Bedminster District.*—The next district undertaken was part of the parish of Bedminster, and situate on the south side of the river Avon, which is drained by the main sewer commencing in East Street, passing into and along Dean Lane, under Nelson Terrace and Coronation Road to the tidal river, main branch sewers being constructed along the several principal streets of the district; also a separate sewer, called Parsons-Street sewer, was constructed for a portion of this district, passing along Parsons Street under the main road to Bedminster Down, along Duckmoor to the tidal river.

3rd. *Clifton Low-Level District.*—The main sewer of this district may be called an intercepting sewer, as it passes in nearly a parallel line with the floating harbour and the river Avon; it is also constructed sufficiently large to receive the drainage from a portion of the Frome district to be hereafter described.

It commences in Hotwell Road, near the bottom of Jacobs Wells Road, and continues along Hotwell Road in front of Dowry Parade, St. Vincent's Parade, thence underneath the rocks in front of Point House to the outlet of the High-Level sewer district.

4th. *Saint Philip's District.*—This district is situate on the east side of the borough, and is bounded on the north by the river Frome, on the west and south by the floating harbour, and on the east by the boundary of the borough. This district was partially drained by the Bread-Street culvert already described; but a new sewer has been constructed, commencing at Baptist Mills, and continuing along the south side of the river Frome, so as to intercept all drains discharging into the said river as far as Haberfield Street, up which it passes and continues along Captain Carey's Lane, and underneath Old Market Street, John Street, St. Philip's Plain, Bread Street, into and along Cheese Lane and Avon Street to the Feeder, under which it passes and continues along the Feeder Road to the tidal river.

5th. *Frome Intercepting Sewer District.*—This district lies on the north side of the river Frome, which river formerly received the drainage of the district.

This district has been divided into separate areas, and is now drained by means of two main sewers, one for the higher ground, and the other for the lower level. The first named commences at the boundary of the borough in Stokes Croft Road, at which point it receives the drainage of Horfield Parish; passing down Stokes Croft Road it continues along Jamaica Street, in front of the Infirmary, along Upper Maudlin Street into Trenchard Street, passing the bottom of Lodge Street, into Frogmore Street to the bottom of Park Street, continuing along College Street, passing the back of the gas-works at Canons Marsh, and discharges into the Low-Level district of Clifton, before described, and the tidal river.

The Low-Level main sewer of this district commences at Baptist Mills on the north side of the river Frome, and passes under Ashley Road and under the new road leading into Newfoundland Lane, continuing along Newfoundland Lane, Milk Street, Clarke Street, and Rosemary Street into Broadmead, passing under the river Frome into Nelson Street, and formerly discharged into Mylne's culvert and the tidal river, but now discharges into the Prince-Street sewer hereafter described.

These sewers with main branch sewers up Ashley Hill complete the drainage of this district.

6th. *The Avon Intercepting Sewer District.*—This is the last remaining district, and is bounded on the north side by the floating harbour, and on the east by the St. Philip's district. It comprises nearly the whole of the old city, which, as before stated, was fairly drained by the late Commissioners; and the existing sewers have been made available by constructing new sewers on either side of the river Avon, so as to connect the whole and discharge the sewage at present at three points in the river; and eventually the sewage of this district on the north side of the river will be connected with the Main-Outlet sewer on the south side of the river, hereinafter described, by means of iron siphons passing under the river from the north to the south side, and discharged at one point near Clift House.

In considering the drainage for this district, it was also necessary to determine the levels for the Main-Outlet sewer, with a view, if necessary, of continuing the same to the mouth of the river, a distance of about 7 miles; and the portion now constructed is laid at such level as to allow of its being so continued at the same gradient, and to discharge at a level of 3 feet above low-water mark, which will allow of free access to the valves &c. at the mouth for about three or four hours each tide.

The principal sewers in this district are the main sewer on the south side of the river Avon, and the Prince-Street sewer. This latter commences at the stone bridge, at which point it now receives the sewage of the Low-Level sewer of the Frome district; it then continues underneath the Tontine warehouses and Clare Street, along Marsh Street and Prince Street, underneath the floating harbour to a point in front of the Gaol, and discharges into the tidal river. This sewer, with the main branch sewers constructed on the north side of the river, and the old sewers constructed by the late Commissioners, completes the drainage of the portion of the district north of the river Avon.

The main sewer on the south side of the river Avon commences at a point opposite Totterdown Lock, above which is situate the outlet for St. Philip's district, and also the outlet for the St. George's district, lying outside the Borough of Bristol, but which by arrangement has been allowed to pass through the borough to this point; and the new sewer has been constructed of sufficient size and at such levels as to receive the sewage from these two districts by means of iron siphons, to be laid under the river; the sewer then continues along the side of the river until arriving opposite to Mylne's culvert and Prince-Street sewer; it then continues along Coronation Road, passing the outlet for the Bedminster district and Mr. Drake's tan-yard, continuing underneath the fields at the back of Clift House, and discharges into the tidal river for the present through the outlet described as Parsons-Street sewer, thus intercepting the whole of the sewage on the south side of the river Avon, and providing for the conveyance of all the sewage now discharging into the river above Cumberland Basin.

From the foregoing it will be seen that these drainage works have been designed and constructed for the delivery of the whole of the sewage now discharging into the river above Cumberland Basin, at one point near Clift House, by means of three iron siphons, to be laid under the bed of the river from the outlets of the following districts, viz. 1st, St. Philip's and St. George's districts; 2nd, Redcliff Hill; and 3rd, Mylnes or Prince-Street district; the only points of discharge will then be the Clifton outlet on the north side, and the outlet near Clift House on the south side of the river.

Having brought the sewage of the borough to these two outlets, the question to be determined is, In what manner shall the same be dealt with? and until this point is settled the writer has recommended that all the present five outlets be retained, viz. four on the north side, and one on the south side of the river.

The sizes of the several sewers in each district are calculated to carry 5 cubic feet or 31¼ gallons per head per diem, for a variable population of from 30,000 to 50,000 per square mile, according to the district, and ¼ inch of rainfall in twenty-four hours, storm overflows being formed in all cases where possible to provide for any greater rainfall.

The question of ventilation, after many years' consideration and discussion, and after the experience of other localities, has been left in the same position as found by the writer, viz. the sewers are without any external openings or means of ventilation, the whole of the street gullies are trapped, and the manholes are all closed down, in which particulars the sewers of Bristol differ from those of nearly all other towns, all external air being excluded. The several districts have for the most part separate outlets into the tidal river, as before described, in all of which districts, with one exception (that of the High Level of Clifton), provision has been made for flushing from the floating harbour or watercourses discharging into the harbour; but in no case has it been found necessary to have recourse to artificial flushing, there being no deposit in any of the new sewers; nor has it been found necessary to provide other means of ventilation. But in the High-Level district of Clifton, it was found that during low water, when the outlet was exposed, the draught in these sewers was sufficient to drive the sewer-air into some of the houses, and an air-valve was placed at the top of the incline to the outlet, which has prevented such draught. The whole of the other sewers, being low-level sewers, have double tidal valves fixed at their outlets. These valves are self-acting, of cast iron, and oval in form; they are hung with chains and bedded on india-rubber.

In February 1871 the writer reported on a proposal for dealing with the sewage of the borough by discharging it only on the ebb of the tide.

The outlets of the present sewers being provided with self-acting valves, which open with the receding tide and close with the rising tide, it was proposed to provide means for preventing the discharge of the sewage during the up-flow of the tide, previous to the closing of the valves, by means of penstocks and storage tanks.

From a series of float experiments it was found that during spring-tides the sewage would be carried down the Bristol Channel nearly as far as Portishead, and would return in such a diluted form as not to be in any way offensive, but that during neap-tides and all tides below 22 feet in height, no portion of the sewage would pass out of the river, but would flow backwards and forwards with each tide, until the return of the spring-tides, when it would be carried out into the Bristol Channel as before stated; and on referring to the Tide Tables it will be found that about 226 of these low tides occur each year.

Under these circumstances it has been determined not to incur any further cost in the matter until such time as the Report of the Rivers Pollution Commission is published, or some Act of Parliament is passed requiring Local Boards and sanitary authorities to deal with all sewage discharged into the tidal river.

In November 1873 the writer reported as to the practicability of uniting the two outlets by bringing the sewage of the north side to the site near Clift House, this site having been approved of by Mr. Robert Rawlinson, C.B., as in all respects suitable for dealing with the sewage in any manner that may be determined on; and it was proposed to accomplish this in one of two ways, viz.:—

First, by carrying the sewage across the river by means of iron siphons at or near its present outlet, and then by sewers to be constructed along the south side of the river to Clift House.

Second, by means of iron siphons carried under the river at or near the new entrance-lock gates at Cumberland Basin, at which point the sewage of the Clifton Low-Level district, and the portion of the Frome district, could be intercepted and conveyed to the south side, leaving only the Clifton High-Level sewage to be dealt with; and as the level of this district is so much above that of the Low-Level district, advantage could be taken of the length of sewer now conveying the Low-Level sewage to the High-Level outlet, by using this length of sewer as a siphon, and forcing the sewage from the High-Level district against the gradient of the sewer to the same point near the new lock-gates to Cumberland Basin, now proposed for the conveyance of the sewage of the Low-Level district, by means of iron siphons across the river to the south side, to be continued thence by double or single culvert, as may be hereafter determined, to the proposed outlet near Clift House; and the only objection to the same is the use of the present sewer with the gradient the reverse way to the flow of the sewage; but this objection could be met by providing means for periodically flushing this length of sewer; at the same time it will be a question, to be hereafter determined, if it will not be better to adopt the first-named plan; the whole sewage of the borough would then be brought to the one site near Clift House, and could be dealt with in any manner that may be hereafter decided upon.

In conclusion, it will be seen that at present no determination has been arrived at with regard to the ultimate disposal of the sewage of the borough, which is still discharged into the tidal river at the five separate outlets. The total cost of the drainage works to the present time, less £6161 paid by the St. George's district, has been £154,743, which, taking the estimated population of the borough at 196,186, will give as the cost per head 15*s*. 9¼*d*. This amount has been raised by rates in each separate district, varying from 1*s*. 6*d*. to 2*d*. in the pound. The whole cost in the two first-named districts having been repaid, the special rates have ceased; in the next two districts it will expire in 1878, in the fifth district in 1880, and in the last district, the amount borrowed having been spread over thirty years instead of twenty years as in the other districts, the repayment will extend to the year 1901.

The average death-rate before the construction of the foregoing works was 28·0 per 1000, and for the year ending January 1875 it was 22·7.

On the Prevention of Sand Bars at the Mouth of Harbours.

By C. Bergeron.

Roberts's Patent Communicator for Railway Trains.

By Walter R. Browne, *A.I.C.E. &c.*

The apparatus consists of a small standard mounted sideways on the roof of the carriage and carrying a short inclined tube, open at the upper end. From the lip of this tube or holder light cords are conducted into each compartment of the carriage; and on pulling any one of these cords the lip is drawn down and the tube reversed. A small counterweight, in the form of a flag, attached to the tube by an arm, prevents its returning to its former position, and at the same time shows at a distance which holder has been reversed.

The communicating cable is in the first instance coiled round a light drum or reel; it consists of two copper wires perfectly insulated, and further protected by a stout waterproof sheath. At intervals corresponding to the length of a carriage short branches are led from each of these wires and taken through the sealed top of a small wooden tube about 4 inches long (denominated a "tipper"), whence they terminate in two adjacent platinum points. The tipper, which is solid at the other end, also contains a small quantity of pure mercury.

The two batteries and bells, one for the locomotive the other for the guard's van, may either be fixed in their respective places, or mounted inside a reel provided with the wire and tippers, in which latter case there are absolutely no electric connexions whatever to make, the cable being paid out either way from the centre of the train, the wire of the two reels being continuous. In the former case the cable is connected to the locomotive battery, then paid out along the train, the surplus wire on its reel being placed in the guard's van alongside the second battery.

The tippers are normally in a more or less upright position, and the mercury in each remains at the bottom away from the wires. On reversing the tipper the mercury flows downwards upon the wires, and thus causes both bells to ring.

After a passenger has once pulled over a tipper he cannot replace it, and the red disk or flag makes detection easy.

If desired the cable forms a ready means of intercommunication between guard and driver at all times.

Should a train part from a broken coupling, the cable will necessarily break; but before doing so the two tippers adjacent to the break will have been reversed, thus calling attention of both driver and guard.

On the Bristol Port and Channel Dock at Avonmouth, near Bristol.

By JAMES BRUNLEES, *C.E.*

The site of the dock is so chosen that the centre line of the lock passes through the centre of the mouth of the Avon, or what is known as the Swashway entrance from Kingroad. Between the Swashway and the lock there will be a deep channel, or approach, 450 yards long by 100 yards wide. The part immediately in front of the dock has a bell-mouthed shape, the side diverging from the centre line of the lock at an angle, and forming a tidal basin of about two acres in area. The lock is 600 ft. in length, 70 feet wide from cope to cope, and has a depth of water on the lower sills of 41 ft. 6 in. at high water equinoctial spring-tides. The dock itself is 1400 ft. long by 500 ft. wide, and has an area of 16 acres. It will have a depth of water of 35 ft. at high water equinoctial springs, 31 ft. 3 in. at ordinary springs, and 22 ft. 3 in. at ordinary high-water neaps. By locking vessels in and out at high water of neap-tides 28 ft. of water can always be maintained in the dock.

The formation of a dam in front of the works proved of considerable difficulty, but it was successfully constructed; and although the tide has reached to within 2 ft. 6 in. of its top, it has never shown any symptom of weakness. About 1,320,000 cubic yards of earth have been excavated from the dock-basin and entrance-lock. The excavations for the foundations were made with the help of portable engines for pulling up the earth at the rate of 100 cubic yards per day. A steam-lift pump, throwing up 20,000 gallons an hour, was employed to keep the foundation trenches clear of water.

The construction of the lock is the most important and costly part of the works. The foundations are laid about 6 ft. under low water equinoctial springs, the level of the sand varying only about 12 in. throughout the whole 600 of its length. Above the sand a bed of rubble masonry 6 ft. thick and from 100 ft. to 120 ft. wide is laid, and on this foundation the inverts and walls are built. The length between the inner and outer cells is 454 ft. This length is divided by a pair of gates into lock-chambers, the outer 204 ft., and the inner 250 ft. in length. The sluice-ways for filling and emptying the locks are formed in the interior of the side walls. They are 7 ft. by 4 ft. 6 in. culverts, having brick arches and inverts and ashlar sides. About 60,000 cubic yards of masonry have been put into the lock, a quantity that represents about 100,000 tons of stone. The stone used in the works is of various kinds, according to the situations and uses in and for which it is applied. The dock walls are 20 ft. thick at the bottom, and gradually reduced to 7 ft. thick at the top. They have a curved batter on the inner face on a radius of 157 ft. The lower foundation is of blue lias concrete, and over it Portland concrete to 2 feet below the floor of the dock, where the masonry commences. The dock-gates, originally intended to be of iron, consist of oak keel and mitre-posts and cross pieces of pitch pine. The lower gates are designed to retain a 41½-ft. head of water. On the rib next the sill the pressure of the water is about 1¼ ton per square foot, and the total stress resulting on the sectional area of the rib is 77·3 tons. The leaf is 3 ft. thick at the centre, and 2 ft. 8 in. at keel and mitre-posts, so that the effective sectional area of the rib is 384 square inches, and the stress on the square inch about one fifth of a ton. The total weight of one leaf of the lower gate is eighty nine tons. There has been a double line of railway constructed, at the joint expense of the Great Western and Midland Railway Companies, to connect the dock with the respective systems of those Companies, and that will bring the dock into communication with all parts of England.

On Chrome Steel. By Col. CARRINGTON, U.S.A., LL.D.

On Sharpness Docks. By W. B. CLEGRAM, *C.E.*

On Toughened Glass. By J. D. COGAN.

On a System of Audible Signals for Railways. By Messrs. CRICHTON & CRAIG.

The object of this invention is to prevent a class of accidents of very frequent occurrence, viz. those that arise from non-observance of signals. The desired end is attained by self-acting apparatus, causing the engine whistle to sound when a driver inadvertently passes a danger-signal.

The inventors have found that the following qualities are essential to apparatus for this purpose, and they trust it may be found that they have been successful in embodying the same in the system described:—

1. The impact of apparatus fixed on the line against that upon the engine must not cause injury to either.
2. Special provision must be made to counteract the tendency to carelessness that usually results from the employment of automatic machinery.
3. The apparatus should be constructed so that it cannot be kept out of action either through negligence or improper motive.
4. It should be solely auxiliary, and in no way a substitute for the appliances at present used in securing safety.
5. It should be capable of being adapted to the various types of engine.
6. The apparatus on the line should be easily actuated and not liable to derangement from contingencies of weather.
7. The whole should be of simple construction and thoroughly reliable in action.

Description.—At each distant signal a simple piece of mechanism is placed beside the line of rails. It may be described as a bell-crank connected by a wire to said signal, so that both work in unison, *i. e.* an arm of the bell-crank moves towards the rails at the same time that the semaphore arm rises to danger, and recedes when the semaphore arm falls.

The engine carries a vertical rod, which is free to slide in a protecting tube attached to the side of the "cab." This rod is connected at its *upper* end to a lever, which acts upon an arrangement for sounding the whistle, precisely the same as that now extensively used for the passenger's communication. (The same mechanism may serve both purposes.) The *lower* end of the rod is formed hollow, and receives one end of a staff or *baton* of wood which rests on a bracket. The baton when put into this socket cannot afterwards be withdrawn without being broken, as it is held by means of a spring catch, which is inaccessible so long as the baton remains whole.

The action of the apparatus is as follows:—So long as the driver does not require to pass within a danger-signal for protection the apparatus requires no attention. When he finds this necessary, it is his duty to raise the vertical rod carrying the *baton*, which is thereby removed from a position where it would be broken by coming in contact with an arm of the "bell-crank" on the line. This action is accompanied by a sounding of the whistle, which prevents the driver from keeping the baton out of the normal position after passing the signal. It also gives the necessary warning to signalmen and others that a train is approaching. Should a driver *inadvertently* pass a danger-signal, the baton, not having been moved into the position of safety, must of necessity be broken at a point made specially weak. The vertical rod being thus deprived of support falls, and by means of its connexions causes the whistle to sound, at once giving warning of danger and recording the driver's negligence. When a baton has been broken, the lower part of the vertical rod protrudes from the tube in which it slides and allows the spring-catch to become accessible, so that the part of the baton remaining in the socket can be withdrawn and a new one substituted. The batons are to be supplied to engine-drivers at such a price as may be considered sufficient to secure the necessary vigilance in preserving them. A simple and efficient way of preventing counterfeit would be to place a seal on the weakened part.

As usually constructed automatic signals act on every occasion that a danger-signal is passed. The effect of this is necessarily to induce reliance on the apparatus. By the system which has been described, the driver has a certain duty to perform at every danger-signal the neglect of which will subject him to pecuniary loss, and also, if of frequent occurrence, to dismissal. There is therefore every reason to expect that the vigilance of the driver would be fully maintained.

The "block system" has now been very extensively adopted, and the apparatus used in connexion with it is being improved in order to eliminate the element of human fallibility in so far as the operators are concerned. But if it is important to get signals duly *exhibited*, it is equally important that they be *attended to* when exhibited. It is therefore evident that the "block system" cannot work satisfactorily so long as its efficiency depends exclusively upon the semaphore-signal, which appeals to the sense of sight alone, and, especially when there is fog, is often passed unnoticed by drivers.

On the Trials of Screw Steam-Ships.

By WILLIAM DENNY, *Leven Ship-yard, Dumbarton.*

The object of this paper was to further the adoption of the progressive method of trying steam-ships on the measured mile.

The present method is, as a rule, confined to maximum power speeds, or to speeds which are the maximum effects of half-boiler power. Such trials afford only meagre and isolated results, giving little if any basis for the comparison of different steamers, and they cannot, as they ought to, show the varying relations of power and speed throughout the range of any steamer's possible speeds.

The ratios of these relations are very unlike in different steamers, and a knowledge of them must be the basis of any true method of comparison. Mr. Froude's resistance-curves, formed from model experiments, are a very good illustration of the objects to be attained by progressive trials, which, when set off on suitable scales, should show at once the relation existing between any speed and power within the limits of the experiments.

For example, a vessel capable of such a series of speeds might be tried at or about 13, 11, 9, 8, and 5 knots, the resulting mean speeds and developments of power being set off and formed into a curve; and it is very evident such a curve would show more easily than any number of single trials the progressive difficulty of driving the ship.

It must be clear to any unbiassed mind that a method which is of absolute importance in the trials of models, can be of no less need in the concrete trials of ships' engines and propellers made on the mile. Of course, curves of revolutions per minute, ship percentages and constants, according to any formula, can also be set off with the simple speed and power curve.

Such curves were shown in the diagrams illustrating this paper, and included, besides specimens of trials conducted by the author's firm, others conducted by Messrs. A. and I. Inglis and the Admiralty.

The constant curve shown in each case was set off to the numbers of the Admiralty midship-section formula, but represented equally well, with suitable scales, the Admiralty displacement and Prof. Rankine's augmented surface constants. Had the theory been true that the power required for propulsion varied as the cube of the speed, these constants would not have been curves but straight lines parallel to the base of the diagram. As they were very marked curves, and, indeed, far removed from any approach to horizontal straight lines, they indicated an equally great fault in all the three formulæ. An examination of the curves showed this fault to be the acceptance of the fallacious theory that the power varied as the cube of the speed.

In none of the diagrams and in no progressive series of trials submitted to the author had this fallacy even the shadow of a sound support; and had Professor Rankine known the extent and worthlessness of it, he would never have been tempted to prove his theory underlying the augmented surface formula from the 'Warrior's' highest speed trial, as two other trials exist, taken at the same draughts and within a few days of each other, which contradict it. In one of the speed-curves shown to the Association, the horse-power varied from ratios in the square to ratios nearly in the fifth power of the speed.

Had Professor Rankine possessed such sets of trials as the practical world should have supplied him with, his great skill would have doubtless drawn from them some very valuable teachings, instead of the formula of the augmented surface, which for every purpose (seeing a comparison of steamers is rendered impossible by our ignorance of their progressive speeds and powers) is of no more value than the Admiralty formulæ it was intended to supersede. Beyond this these curves go to prove that in the expenditure of power in relation to speed, within the limit of the highest ocean speeds now in use, marked speeds peculiar to the vessel are seldom likely to be apparent, excepting they be found by some such empirical formulæ as those referred to. These formulæ show apparent speeds of maximum efficiency; but they are only apparent, and depend upon the theoretical power of the speed in which the horse-power is supposed to vary. Different speeds of apparent maximum efficiency will appear as the square, the cube, and the fourth and fifth powers of the speed are selected.

Indeed if we are ever to get a tolerably good formula for finding speeds and power, which is doubtful, it will not be found without progressive trials combined with and checked by such experiments as Mr. Froude is now making on models.

Regarding the conduct of progressive trials, it is of primary importance that their accuracy in all parts should not fall below the Admiralty standard, and that a calm day should be chosen for their performance. The wind has a most disturbing influence on the slow speeds. In the engine-room, the head of it must not only control his observing staff, but must carefully regulate the development of power on each pair of runs. Any great inequality will vitiate the results of the trials. In fact progressive trials without honesty and accuracy will be failures.

A small copy of the speed-power, revolution, Admiralty midship and section constants, and ship percentage curves of the screw steam-ship 'Taupo,' built and tried by the author's firm, is appended (see fig. 5, Plate XIII.). After the remarks already made, this diagram will be clear. Small circles mark the points of mean speeds observed on trial.

Note.—Mr. Denny's paper is printed in full, with the original diagrams, in 'Engineering,' for October 15th 1875, vol. xx. p. 311.

On the Bristol joint Station. *By* FRANCIS FOX, *C.E.*

On a Steel Gradient Formation. *By* H. HANDYSIDE.

On Block-signalling on Railways. *By* R. R. HARPER.

On Improvements in the Clockwork of Revolving Lighthouses.

By J. HOPKINSON, *D.Sc.*

Until recently the machinery driving the apparatus of revolving lights has always been controlled by revolving fans, which slightly mask the variations of friction in the machine and rollers which carry the light by adding a considerable resistance of the air, which increases slowly with the velocity. A light thus governed goes, at the best, if carefully regulated by the lightkeeper, too slow at starting, whilst the lantern is cool and the lubricating oil thick, and too fast when the apparatus has run some time. The lightkeepers endeavour to correct this acceleration by taking off driving-weight. It is perhaps true that a careful man, with the fan arrangement, or indeed without any governor at all, by adjusting the driving-weight, may keep his apparatus so near to time that there would be little danger of mistake. But it is undesirable that the want of such care should cause such serious risks, if it can by any means be avoided. As a matter of discipline, too, it is advantageous that an absolute rule may be laid down that *no* sensible variation of velocity is permissible; and if it occurs, it should be only attributable to interference with the machine, insufficient driving-weight, or neglect of winding up, for either of which the lightkeeper is responsible. With fans it was necessary that a certain error should be tolerated; it is better that *any* error should condemn the lightkeeper.

In the apparatus made at the works of Messrs. Chance during the last year, I have replaced the fans by a centrifugal governor, in principle the same as those of Sir William Thomson and Mr. Grubb. It consists of a weight in the form of a disk, sliding on a vertical revolving shaft, guided by feather keys. Two governor balls, carried by arms which make an angle of about 45° with the shaft, are connected with the disk by links, so that in expanding they lift the disk from the collar on which it rests when below speed. Two adjustable screws, tipped with leather, are fixed to the frame of the clock above the outer rim of the disk. As soon as the disk is lifted from the collar it comes in contact with these brake-screws. Since the disk has a diameter of 12 to 16 inches, and makes over a hundred revolutions per minute, the friction has sufficient moment to control the rotation of the apparatus. Indeed the clock goes at sensibly the same speed whether the apparatus, weighing about a couple of tons, is in gear or at rest. A little thumbscrew pressed at pleasure against the edge of the disk serves to instantly stop the clock. With the exception of Sir William Thomson's clock at the Holywood Bank, and those arranged by Mr. Douglas for light-vessels, the clocks made by Messrs. Chance during the last year are the only ones in use for revolving lights capable of going any thing like uniformly. This governor almost places it beyond the power of the lightkeeper to make his apparatus go wrong. Deficient weight he will be compelled to correct; for the friction of the apparatus being constant, and the governor not acting when below speed, the machine will slowly stop.

In most lighthouse clocks, whilst the driving-weight is wound up, the motion of the apparatus is either allowed to take care of itself, or is maintained by a weighted lever acting on a ratchet-wheel, and spasmodically lifted by the act of winding. With the fan-governor this must interfere with the regularity of the motion, and in any case it jerks the machine. The author finds it best to return to the oldest maintaining arrangement, that of Huyghens, in which an endless chain or rope passes over separate winding and driving pulleys, and hangs in two loops, of which one passes under a snatch-block to which the weight is hung. The chain passes continuously over the driving-pulley as it revolves. The author cannot understand why this old and simple plan is not used for turret-clocks. With suitable pulleys, and a chain of moderately accurate pitch, the clock works perfectly smoothly, and is absolutely unaffected by the operation of winding.

A Scheme of Water-supply for the Villages and Country Parishes of the Central and Eastern Counties of England. By Professor HULL, *F.R.S., Director of the Geological Survey of Ireland.*

After referring to the prevalence of zymotic diseases in villages, hamlets, and country parishes, admittedly due to "dirt" (which, as Lord Palmerston defined it, is "matter in the wrong place") and bad water, the author proposed to deal with the latter evil by a scheme applicable to the central and eastern counties of England. This scheme was only intended to apply to those districts which come under the division of "Rural Sanitary Districts" of the Public Health Act of 1872, the "Urban Sanitary Districts" being provided for by local resources and engineering skill; but the author maintained that in a large number of instances the villages and hamlets required the introduction of some system of water-supply quite as much as the larger towns and cities.

The author's proposal involved a double system of supply applicable in two different sets of cases, (1) either by means of wells, or (2) when wells were inadmissible, by surface streams. He proposed, as a preliminary step, that, by the aid of the Rural Sanitary Officers appointed under the Act of 1872, returns should be obtained regarding the water-supply at present in existence in the villages and hamlets throughout the central and eastern counties. These returns were to be transmitted to the Central Board of Health in London, and from them it could be determined what were the cases requiring the application of a scheme of supply.

The author then proceeded to point out how favourably circumstanced were those districts of England to which his observations applied for a system of supply by means of wells of greater or less depth. These districts were formed geologically of the Mesozoic or Secondary strata, included between the Lower Tertiary strata above and the Permian beds below. And it would be found that they were capable of being grouped into an alternating series of permeable (or water-bearing) strata on the one hand, and impermeable (or dry) strata on the other.

The permeable strata were grouped as follows:—1. Chalk and Upper Greensand. 2. Lower Greensand. 3. Purbeck and Portland Beds. 4. Coralline Oolite and grit. 5. Great and Inferior Oolites and sands. 6. Middle Lias, or Marlstone. 7. New Red Sandstone. Attaining a combined thickness of 1,275 to 5,600 feet.

The impermeable strata were also grouped as follows:—1. Gault Clay. 2. Kimmeridge Clay. 3. Oxford Clay. 4. Upper Lias Clay. 5. Lower Lias Clay and Keuper Marls. Attaining a combined thickness of 2,100 to 5,000 feet.

It was shown, by reference to the Geological Map of England, that these groups of strata, alternating with each other, were spread out over considerable areas, and dip one underneath the other at very moderate inclinations, owing to which the waters collected from the rainfall over the permeable strata percolate downwards till stopped by the underlying impermeable strata, forming underground reservoirs which might be reached by wells or bore-holes.

It was also shown that those underground waters pass for long distances under the overlying impermeable formations in the direction of the dip, and could be reached and rendered available by wells or borings on the Artesian principle.

As an illustration of this, the author referred to the deep boring recently made at Scarle, near Lincoln, where, after the impermeable Lias and Keuper Marls had been passed through, the water-bearing beds of the New Red Sandstone were entered, and a fine fountain of water rose through the bore-hole above the surface of the ground. In this instance the water had travelled 12 to 16 miles underground, from the outcrop of the water-bearing sandstones near Mansfield. The author then described the qualities of the waters yielded by the different formations as shown by numerous examples submitted to chemical analyses.

From the knowledge now possessed on such subjects, it was certain that, by means of wells or borings, supplies of water could be obtained, not only in localities situated on water-bearing strata, but on those situated on the overlying impermeable strata, according to depth. At the same time there would necessarily be a large number of villages and hamlets where the depth to the water-bearing beds and the cost of reaching them would be too great for the resources of the inhabitants. These would have to be dealt with by other means of supply.

In order to carry out a general scheme applicable to all villages found, from the returns of the Medical Officers of Health, to be insufficiently or improperly supplied, the author proposed to utilize the maps of the Government Geological Survey, now nearly complete, for the districts referred to, and on which the areas of the water-bearing and impermeable formations respectively are accurately laid down. With the aid of these maps (which were easily obtainable) it could be determined by the Local Sanitary Authority whether any special village or hamlet was so situated as to be capable of receiving a supply by a well of reasonable depth. In case of necessity, however, professional advice might be called in; but the author considered that, owing to the special nature of such cases, it would be necessary to have a geologist of experience attached to the Central Board of Health, whose duty it would be to advise with each Local Sanitary Board as occasion might arise. This officer should also assist in the selection of a proper site for a well, and afford data for determining the depth and cost of sinking, &c.

Upon the report by the Officers of the Local Board of Health, certified by the Government Adviser, of the feasibility of a plan of water-supply by a well or borehole, an order should issue for the compulsory carrying out of the work, and powers should be vested in the Local Sanitary Authority to raise money for the purpose.

The well thus constructed should be carefully preserved from pollution, and be accessible to the inhabitants of the village or hamlet comprised in the order; and all objectionable or impure sources of supply should be destroyed or stopped up.

In cases, on the other hand, where it is found that, owing to the position of any village or hamlet in reference to the subjacent water-bearing formation, the depth and cost would be too great for the resources of the inhabitants, then it would be necessary to have recourse to the most suitable stream or brook, which should be put under strict regulation as regards the prevention of contamination. The author proposed that in such cases small tanks should be constructed for storage of the waters in winter, and should be vested in the Local Sanitary Board, who should be responsible for their due preservation.

In conclusion the author expressed his opinion that the time for carrying out some general scheme of water-supply for the too greatly neglected villages and country parishes had come, and which he considered might be carried out by combining the information to be derived from Geological Survey maps with the power granted under the Public Health Act of 1872. He considered that any scheme to be of use should be both compulsory and of general application. He also considered that until every village and hamlet, as well as every town and city, had a constant supply of pure water for domestic purposes, sanitary legislation could not be considered to have effected its purpose.

On a Sewer-Trap. By HENRY MASTERS.

On the Severn Tunnel. By CHARLES RICHARDSON, *C.E.*

On the Tidal Scour in the Severn. By CHARLES RICHARDSON, *C.E.*

Tides in the Irish Sea. By JAMES N. SHOOLBRED, *C.E.*

At the Easter equinoctial tides in 1875, a series of simultaneous observations were carried on at several points on the English and Irish coasts of the Irish Sea, on March 31st and on April 8th, the calculated least neap and the greatest spring of the year.

On the English side, at Whitehaven, Barrow, Fleetwood, Liverpool, and Holyhead, and on the Irish one at Belfast, Dundalk, and Dublin, simultaneous observations were obtained, generally under the direction of the Engineer in charge of the port.

The English observations, taken by Greenwich time, have been reduced to a uniform level of 100 feet below the Ordnance datum of Great Britain; while the Irish ones, where Dublin time was observed, were reduced to the Ordnance datum of Ireland. And as the difference between each Ordnance datum and the mean level of the surrounding sea has been ascertained, it is possible, by assuming uniformity in the mean sea-level, still further to compare directly the two systems of levels with each other. From a general comparison of these tidal data the following conclusions may be roughly drawn.

1st. That the time of H. W. at all the points of observation is practically the same, allowance being made for the disturbing influence of weather; and the same remark applies to L. W.

2nd. That the level of H. W. at all points (*actually within* the Irish Sea) on each coast, taken *separately*, is nearly identical; and the same may be said of the level of L. W.

3rd. That the tidal range on the English coast is about double of that on the Irish side.

In explanation of these peculiarities it must be borne in mind that there are two tides which set into the Irish Sea—the northern one round the north of Ireland, and the southern one coming from the English Channel, the meeting of the two being somewhat along a line drawn from Fleetwood across to Dundalk.

Captain Beechey, R.N., who some years back made considerable researches as to the tides of the Irish Sea, described them under the name of "Stationary Tide," in contradistinction to the "Progressive Tide," where the times of H. W. and of L. W. at different points vary with the distance previously travelled by the tidal wave. The result of the above-named simultaneous observations has been on this head to confirm positively what Captain Beechey and others had supposed to be the case.

The greater range of the tide on the English side, 30 feet at equinoctial springs as against 15 feet, may be accounted for by the shallow water of Morecambe and Liverpool bays and along the English coast, where, under well-known tidal laws, a considerable heaping up and a corresponding depression might be anticipated.

At equinoctial springs the H. W. on the English side stands about 7 feet *above*, and at L. W. about 7 feet *below* that on the Irish coast; while at equinoctial neaps the excess on the English side, both at H. W. and at L. W., is reduced to little over one foot.

Tides in the Irish Sea.

	L. W.		H. W.		L. W.		Remarks.
	Time.	Height	Time.	Height	Time.	Height	
Equinoctial Spring-Tide, April 8, 1875.							
	h m	ft. in.	h m	ft. in.	h m	ft. in.	
Whitehaven	6 45 A.M.	86 0	12 45 P.M.	113 0	7 15 P.M.	86 0	N.N.W. strong breeze.
Barrow ...	8 30 "	84 3	1 30 "	114 11	9 0 "	83 7	N. light, 29·80.
Fleetwood..	7 15 "	86 9	12 45 "	115 8	7 45 "	87 0	N.E. gale, 29·50.
Liverpool ..	6 45 "	84 2	12 noon.	113 11	7 15 "	83 7	N.N.E. strong, 29·73.
Holyhead...	5 15 "	89 8	11 30 A.M.	108 2	5 45 "	89 1	N.E. strong.
							[30·20.
Belfast	6 0 "	95 10	12 15 P.M.	105 10	6 15 "	94 10	N.E. strong breeze,
Dundalk ...	7 50 "	93 8	12 15 "	108 0	8 00 "	93 10	N.E. strong breeze,
Dublin	6 0 "	93 2	12 45 "	106 2	6 15 "	92 8	N.E. strong. [30·0.
Kingstown	5 45 "	92 7	12 45 "	105 1	6 15 "	91 11	N.W. strong, 29·87.
Equinoctial Neap-Tide, March 31, 1875.							
Whitehaven	12 15 P.M	94 9	6 15 P.M.	103 7	1 0 A.M.	95 8	Light. [30·60.
Barrow ...	12 15 "	93 4	" "	103 4	" "	94 3	N.W. fresh breeze,
Fleetwood	12 noon.	94 6	" "	104 3	" "	95 1	N.W. calm, 30·50.
Liverpool...	11 45 A.M.	93 4	" "	102 8	" "	94 1	N.N.W. light, 30·60.
Holyhead...	11 0 "	95 8	5 45 "	101 6	12 midn't.	96 6	N.N.W. strong, 30·62.
Belfast	12 noon.	97 10	6 00 "	102 10	12 45 A.M.	98 9	N.N.W. light, 30·60.
Dundalk ...	" "	95 9	7 00 "	102 8	....	....	N.N.W. light, 30·65.
Dublin	" "	97 0	7 00 "	102 2	....	....	N. very light.

Greenwich Time throughout (Dublin time being 25^{m} 21^{s} behind Greenwich).

Datum of levels, 100 feet below English Ordnance.

Assuming the Mean Sea-level to be uniform, Irish Ordnance = 92 feet 6⅛ inches above Datum.

On A. S. Hallidie's Wire Rope Traction-Railway. *By* W. SMITH, *C.E.*

On a means of Recording the Movements of Points and Signals.
By W. SMITH, *C.E.*

On a Breech-loading Mountain Gun. *By* W. SMITH, *C.E.*

On a Military Bidon. *By* W. SMITH, *C.E.*

On Portishead Dock. *By* F. C. STILEMAN, *C.E.*

Position.—The docks are situated on the eastern side of Portishead Hill, which forms a most complete shelter, both to the dock and approaches thereto.

Pier and Outer Works.—A timber pier, having a double line of railway, 540 feet in length, was constructed by the Bristol and Portishead Pier and Railway Company in the year 1870. The new works were commenced by continuing the line of this pier for a length of 430 feet inland, completing nearly 1000 feet of outer quay wall and pier. A return wall, forming the entrance to the docks, and in which the entrance-gates will be erected, is also constructed. All this work has been executed between the times of the tides, or "tidal work."

Dam.—A temporary dam is formed across the future entrance, constructed of wrought-iron girders built into the masonry and planked with timber.

Interior Works.—The tide was excluded on the 10th June, a not sufficiently long time to allow of the inner works being in "full swing." Some portions of the excavation are down to within 2 feet of the permanent level of the dock. The foundation of the dock and wharf wall have been proved to consist of rock and marl.

Lock.—The lock will be 560 feet in length, and 66 feet in width; the sills are 6 feet above L. W. O. S. tides, affording a depth at H. W. of 34 feet at O. S. and 25 at neaps.

Provision has been made for excluding the equinoctial tides by a caisson (already built).

Dock.—The wharf wall will be built (and is just about to be commenced) in the same straight line as the outer wall for a length of 1800 feet.

The area of the dock will be 12½ acres, having a depth of 24 feet. In addition to this, a considerable area covered by water will be available for timber ponds.

Anchorage.—The well-known anchorage ground at King Road is immediately adjacent to the docks.

Railway.—The Bristol and Portishead Railway, in connexion with the railway system and these docks, was opened in 1867.

On Communication between Passengers and Guards.
By Messrs. STROUDLEY & RUSBRIDGE.

On Vertical Motion of Vessels. *By* JOHN I. THORNYCROFT.

The present paper treats on some experiments made to ascertain the vertical motion of a vessel relative to the undisturbed water-surface.

The experiments were made with a torpedo-boat, 67 feet in length and 8¼ feet beam, which had a speed of about 19 knots. The water-surface was measured at three points respectively (1, 14, and 27 feet ahead of the launch) by suspended weights adjusted to its surface, as suggested by Mr. Froude (see Plate XIII. fig. 3), the inclination of the boat and revolutions of the propeller being at the same time noted.

The results are shown in the accompanying diagram (see fig. 4, Plate XIII.), where the horizontal ordinates represent revolutions of the propeller per minute (240 to one inch); the vertical ordinates of the line A, speed of screw; vertical ordinates of the curve B, speed of boat; the curve C, inclination of the vessel in 125 inches; the curve D, motion of centre of gravity relative to water-surface at rest; the curve E, mean reading of the weight No. 3; F, mean reading of weight No. 2; G, mean reading of weight No. 1. In the diagram the vertical scales being—for speed 12 knots per inch, for inclination in 125 inches and vertical motion of vessel 12 inches per inch, for motion of weights 24 inches per inch.

The diagram shows that the vessel sank more deeply as the speed increased to about 12 knots, when almost suddenly, with increasing speed, the boat rises; and this continues up to the highest speed attained, the depression at 12 knots being about 5 inches, and the elevation at 19 knots 3 inches. Thus the greatest change of level observed was about 8 inches.

On a Machine for the Calculation of Tides. By Sir W. Thomson, *F.R.S.*

On Methods of giving Distinctive Characters to Lighthouses. By Sir W. Thomson, *F.R.S., and* J. Hopkinson, *D.Sc.*

*On the Channel Tunnel**. *By* W. Topley, *F.G.S., Assoc.Inst.C.E.*

The author first described the geological structure of the shores of the Straits of Dover, noting especially the water-bearing qualities of the various strata. The most important bed in relation to this question is the Chalk; the upper part of it contains layers of flints, which are wanting in the lower part. Water passes only slowly through the mass of the chalk, but more freely along joints and fissures or along the lines of flint. Below the Chalk come Gault, Lower Greensand, Weald Clay, and Hastings Beds. Of these the Gault and the Weald Clay may be taken as impervious beds. The author then passed on to note the lower beds, which come to the surface near Boulogne, but which are only known in the S.E. of England by the Sub-Wealden boring The various folds into which the strata have been thrown were then noticed, and the relation of these to the structure of the district was discussed.

The author then referred to the various schemes which had been proposed for traversing the bed of the Channel, dwelling in greatest detail upon that of Sir J. Hawkshaw—a tunnel through the Chalk. He alluded to the views of Prof. Hébert as to the supposed existence of a large transverse fold in the Channel, which it was suggested might seriously interfere with the work, by bringing up beds lower than the Chalk along the proposed line of tunnel. He was not prepared to follow Prof. Hébert in his argument, believing that there was no evidence of such difficulties as were suggested. It is frequently supposed that faults in the strata would cause great inconvenience; but the author showed, by reference to actual workings in coal and other mines, that the danger here was exceedingly small, and that there is no reasonable expectation of meeting with a larger quantity of water than can be dealt with by pumping.

The author referred to a proposal, by Prof Prestwich, to construct a tunnel through the Palæozoic rocks; and also to one, first suggested by Mr. H. Willett, for using in this way the Kimmeridge Clay, which occurs in great thickness in the Sub-Wealden boring, and also exists on the French coast. He showed that a tunnel through the Kimmeridge Clay would be quite feasible, the chief objection being its length. He gave a preference to Sir J. Hawkshaw's scheme—a tunnel through the Lower Chalk, and had little doubt that this could be successfully carried out.

On a Machine for obtaining Motive Power from the Motion of a Ship among Waves. By Beauchamp Tower.

This machine consists in principle of a weight supported on a spring, so that it can oscillate on the spring through a considerable range in a vertical line. The scale of the spring, and consequently the natural period of oscillation of the weight, can be varied at will. When it is so adjusted that it synchronizes with the waves, the oscillations become very violent, and a large amount of power can be obtained from them. The theoretical amount of power per minute in foot-lbs. obtainable, when the synchronism is perfect, is equal to 57·7 × the range of oscillation of the weight × the mass of the weight in lbs. × the effective height of the waves in feet, divided by the cube of the period in seconds.

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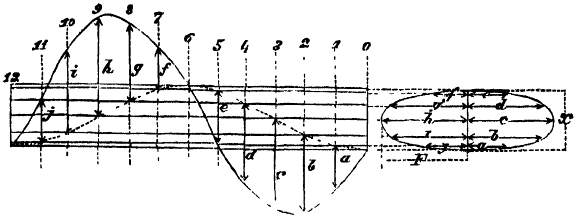
* This subject has been discussed in greater detail by the author in 'Quart. Journ. of Science' for April 1872, and 'Pop Sci. Review' for October 1874.



m = mass of oscillating weight, in lbs.
P = period of oscillation, in seconds.
x = range of vertical oscillation of ship, in feet
y = range of vertical oscillation of weight

Maximum force on spring $= \mathrm{F} = \dfrac{2\pi^2 ym}{\mathrm{P}^2 g}$.

Work per oscillation in foot-lbs. = the area of ellipse $= w = \dfrac{\mathrm{F}x\pi}{2} = \dfrac{\pi^3 ymx}{\mathrm{P}^2 g}$.

Work per minute $= \dfrac{w60}{\mathrm{P}} = \dfrac{\pi^3 ymx60}{\mathrm{P}^3 g} = \dfrac{57\cdot7ymx}{\mathrm{P}^3}$.

The manner in which this result is arrived at is explained by the diagram. The dotted wavy line represents the motion of the ship through one oscillation, and the full wavy line that of the weight. The distances between these two lines are indicated by the ordinates *a*, *b*, *c*, *d*, &c., which also represent the tension of the spring. When the ship is rising the spring is pushing down, and when it is falling the spring is pulling up, thereby affording a resistance against which the ship can work. The ordinates *a*, *b*, *c*, &c., planted as ordinates on a line which represents the vertical motion of the ship, make an elliptical figure, the area of which represents the work taken out of the ship and put into the oscillating weight in one complete oscillation.

In practice the spring would consist of highly compressed air pressing on the rams of hydropneumatic cylinders; and the arrangement is such that the vessel containing the compressed air forms the moving weight. The natural period of oscillation in seconds $= 2\pi\sqrt{\dfrac{c}{ag}}$, in which c is the capacity of the air-vessel in cubic feet, and a is the sum of the area of the rams in square feet.

The author exhibited a design for a machine for working an auxiliary propeller of a sailing-ship of 1800 tons displacement. The moving weight in this case is 200 tons; and he showed by calculation that with a range of oscillation of 20 feet it would give, after allowing for friction, about 30 horse-power in the long swell met with in the tropical calm, 200 horse-power in average ocean-waves, and more than 600 horse-power in a heavy head sea. The space occupied by the machine compares favourably with a steam-engine of the same power.

The author exhibited a model of the machine, which in a moderate sea had yielded power at the rate of 1½ horse-power per ton of moving weight.

On a Revolution-Indicator. *By* BEAUCHAMP TOWER.

The simplest form of the instrument invented by the author is a centrifugal pump. The centre of the pump-case is connected to a small tank, and the periphery to a vertical glass tube. The pump-case and tank contain water. The fan of the pump is rotated by the engine, the speed of which it indicates by the centrifugal force causing the water to rise in the glass tube, and to indicate by its height, corresponding to marks on a scale, the speed, in revolutions per minute, at which the engine is running.

In ships of war it is very desirable that the revolutions per minute should be visible at a glance, both to the engineer in the engine-room and to the officer of the watch on the bridge. This the author effects by carrying two small pipes from the engine-room to the bridge; one of these pipes is connected to the centre, and the other to the periphery of a centrifugal pump fixed in the engine-room and driven by the engine. The pump and pipes are full of water; and the centrifugal force, due to the rotation of the pump, creates a difference of pressure in the two pipes, which difference is the same at any point in the two pipes, and is rendered sensible in the engine-room or on the bridge by a differential pressure-gauge applied to the two pipes, and capable of measuring the difference of pressure. By properly graduating the dials of these gauges, the indications can be read in revolutions per minute of the engine.

Attached to this apparatus is an arrangement for indicating whether the engines are going ahead or astern by means of a small oscillating air-pump, which pumps air into a small pipe when the engines are going astern, and sucks the air out of the pipe when they are going ahead This pipe is carried to the bridge, and connected to a small cylinder containing a piston which moves to one or other end of the cylinder according as the pressure in the pipe is above or below that of the atmosphere. This piston is attached to and moves a piece having the words "ahead" and "astern" written on it, and causes one or other of these words to become visible, as the case may be.

On Steering. By JOSEPH WOOLLEY, *LL.D., Vice-President of the Institution of Naval Architects.*

The only mode of steering considered in this paper is that in which the rudder is the instrument employed, screws placed athwartships, in the bow or stern, and jets of water on the principle of Ruthven's propeller, having been proposed, but never seriously adopted.

Ancient authors always assumed that, in accordance with the received theory of resistance, the resistance on the rudder varied as $v^2 \sin^2 \Phi$, where v is the velocity of the ship and Φ the angle to which the rudder is put over. Modern observations and experience show that this law is incorrect; that the resistance is not uniform over the whole surface, but more effective at the fore than the aft part; and the pivot-balanced rudder gives reason to believe that the resistance of the foremost third is equivalent to that on the aftermost two thirds of the whole surface. It is also now allowed by most competent authorities that the resistance at different angles varies more as the sine than as the square of the sine of the angle. In accordance with the old theory, the angle of maximum efficiency was laid down at 54 deg. 44 sec. Bouguer points out that this angle is too large, and that it ought to be reduced, in consequence of the change of direction of the water particles at the upper or broader part of the ship; and in a general way thinks it should be reduced by at least 7 deg. or 8 deg. Euler, following in his steps, by reasoning analogous to rudimentary stream-line principles, finds that $v \cos \beta$ is the velocity with which the particles of water impinge on the rudder at the part where β represents the angle made by the water-line with the fore and aft lines. He then deduces for the angle of maximum efficiency at that height $90^\circ - \frac{\beta+\gamma}{2}$, where $\gamma = \cos^{-1} \frac{1}{3} \cos \beta$. Thus, if β be 45 deg., this angle is 29 deg. 9 min. But as the angle varies for different water-lines, he concludes in favour of a mean angle of 48 deg., or at least 45 deg.

There is reason to believe that not only does the putting over of a rudder produce a direct resistance on its outer surface (which alone has hitherto found its way into mathematical formulæ), but also increases the pressure on the stern-post and dead wood for a considerable distance forward by checking the velocity, the effect of which on the turning of the ship would form a considerable item in the whole action. This is in accordance with the principle of stream-lines so ably explained by Mr. Froude, in which he shows that a diminished velocity is always accompanied by increased pressure. When the stream has, however, set up a decided current towards the outer edge, the velocity increases and the pressure diminishes. This explains the experimental fact before mentioned, that the fore part of the rudder is more efficient than the after part. In accordance with this view, it is understood that some ships in the royal service are being fitted with the balanced rudder, so arranged that, when under canvas only, not only is the fore part of the rudder turned into a stern-post, and the blades of the screw made to act as dead wood, but additional dead wood is made to run out under the counter, so as entirely to fill up the cavity before the screw.

There are two conditions in the putting over of the rudder to be considered. At the first moment the axis of motion, or instantaneous axis of rotation, is not the centre of gravity, but a point determined as follows:—The first impulse in the rudder is to produce a pressure on it perpendicular to its surface, which on ordinary mechanical principles is equivalent to an impulse applied to the ship at its centre of gravity in a parallel direction, and a couple to turn it round the centre of gravity. In fig. 2, Plate XIII., A is the instantaneous axis, thus formed : B G A is drawn perpendicular to the direction of the water-pressure on the rudder; G D parallel to B C, and equal to the ship's outer radius of gyration round a vertical axis through G; D A is drawn at right angles to B D, cutting B G produced in A. Then, evidently by the construction, $\mathrm{G\,A} = \frac{\mathrm{GD}^2}{\mathrm{GB}} = \frac{\mathrm{R}^2}{\mathrm{GB}}$ gives A the instantaneous axis.

This is only true at the first moment. The ship afterwards shifts laterally until the lateral resistance so created becomes equal to the lateral force on the rudder, and there remains a couple turning the ship round, whose force is the resistance on the rudder, and the arm the distance between the centre of effort on the rudder and the centre of lateral resistance on the ship. This latter point is almost always before, and sometimes very considerably before, the middle point of the ship's length. Hence evidently the stern is the most effective place for the rudder, as nowhere else can this arm be so large; and hence also is the manifest disadvantage of a rudder raking forward from the top downwards, as is sometimes the case in yachts, which arrangement not only diminishes the arm of the turning couple, but practically increases the immersion in consequence of the existence of a vertically resolved part of the water-pressure on the rudder

Sensibility to the helm (*i. e.* quickness and readiness in a ship to go about) is a most important quality. At the first moment the angular acceleration, which is a measure of this sensibility, varies directly as the moment of the water-pressure on the rudder, and inversely as the product of the weight of the ship and the square of its radius of gyration about a vertical axis through the centre of gravity. The moment of water-pressure varies *cæteris paribus* as the area of rudder surface. When large ships were first built the area of rudder surface was not increased in proportion to the dimensions; hence large ships (*e. g.* the 'Achilles') were not handy. Handiness is also diminished by putting heavy weights at the stem and stern, and so increasing the radius of gyration. A short ironclad would thus carry heavy bow and stern guns with less injury to steering qualities than a larger one. The great difficulty under which naval architects lay on the first introduction of large ships was not in making the rudder big enough, but in finding power enough on the wheel to turn them through an efficient angle, rudders of even moderate size being found to require the united efforts of 40 or even 60 men to bring them over to 18 deg. or 20 deg., not to speak of 38 deg. or 40 deg. This difficulty has since been overcome by applying steam or hydraulic pressure to the wheel. In the latter case, however, if Mr. Reed's explanation of the cause of the 'Bessemer' not answering her helm fast enough on steering into Calais harbour be accepted, there seems to be the inconvenience that it requires an appreciable interval of time to move the rudder; and hence for *instantaneous* purposes (*e. g.* getting clear of an obstacle or avoiding a collision) this mode of supplying power is faulty. The period in which a complete turn of a steam-ship is effected and the diameter of the circle described are important elements in the handiness.

On this subject I abridge from M. Bertin's 'Notice sur la Marine à Vapeur de Guerre et de Commerce,' 1875. In fig. 1, Plate XIII., f is the pressure on the rudder O B, and F the resultant of the lateral pressure acting through the ship's centre of lateral resistance and the direct resistance acting on the bows. V is the velocity of the ship in direction G V. Though here the angular velocity has become uniform, G C perpendicular to G V is the diameter of the circle in which the ship turns. A G V is the angle of turning described in a unit of time while the ship moves through the space V. The moment of resistance of the water to the ship's turning, which is nearly proportional to the square of the angular velocity, is equal to the moments of the two forces f and F. The sum of the projections of these forces on the line G C is equal to the centripetal force under which the circle is described, and therefore to $\frac{W}{g} \cdot \frac{V^2}{GC}$. If, then, f and F were exactly proportional to V^2, and made with the axis O A a constant angle, the length of the radius G C would be independent of the velocities, and the period of a complete turn would vary inversely as V. In actual practice the velocity diminishes, the lateral resistance which is due to the small lateral velocity decreases more slowly than the direct resistance which is proportional to V^2, the angle made by G F with G C increases, and the centripetal force decreases more slowly than V^2, and the radius G C diminishes. The circles described thus become smaller at smaller velocities. In comparing similar ships of different dimensions, f and F increase as the square, while W increases as the cube of the dimensions. Hence G C should increase nearly in the direct ratio of the dimensions. Thus the diameter of the circle described by a ship in a complete turn should be about twice that described by a similar ship of half its length

The smaller the diameter of the circle in which a ship turns the more handy she is. Records of the performances of the most handy ships in the English and French navies established five times the length as the limit below which this diameter never falls. Mention has been made of the difficulty felt by naval architects in supplying effective steering-apparatus in lieu of the limited power available in former days at the tiller. M. Barnes, starting from the principle that only a given power could be thus used, made an investigation of the conditions under which this could be most efficiently applied. He established two propositions:—(1) that for the same power to bring over rudders of different breadths to different angles, the breadths should be inversely as the sines of the angles; and (2) that the efficiency of the rudder under such circumstances varies as the sine of twice the angle. Hence, if a rudder of a certain length could be brought over to 15 deg., a rudder of half its breadth could be brought over by the same force to 30 deg., and the efficiency thereby nearly doubled. He recommended subsidiary rudders to be fitted so as to assist the main rudder when required. Such rudders were tried by Admiral Halsted at Sheerness in 1863, but were found to diminish instead of increasing the steering efficiency. This investigation has now little more than an historical interest. It is to be observed that he finds the angle of maximum efficiency to be 45 deg., which, however, on stream-line principles, would require to be reduced to 33 deg. or 34 deg. The law of variation of the resistance which he adopts is that of the square of the sine. If that of the sine alone be introduced, it would seem that the breadths of the rudders should be inversely as the square root of the sines, and the angle of maximum efficiency 35 deg. 16 min., or, practically, 30 deg.

It is often asserted now-a-days that the lower part of the rudder is of no use; and hence the practice of cutting it away has come into vogue. An experiment, however, made by Mr. Froude, which he kindly communicated to me, leaves no doubt that this opinion is erroneous. To a model of the new 'Encounter,' 10 ft. 6 in. long, was fitted a rudder, consisting of two blades of equal dimensions, one above the other, and fixed at an angle of 30 deg. They were governed by the same tiller, provided with a graduated arc, to which it could be clamped; thus, when the angle of one blade was reduced, that of the other was increased to an equal extent. The model was towed by the nose with an arrangement which allowed perfect freedom of motion in a vertical direction, but inexorably resisted any attempt at lateral motion, while the stern was left perfectly free to move sideways in either direction. The set of the rudder was varied until she followed neutrally; and it was found that when she did this, the upper half required just 20 deg. of inclination to balance the lower half with 10 deg., thus proving incontestably the higher efficiency of the lower half. Possibly, however, an advantage may accrue from raising the centre of effort on the rudder, in some cases by reason of the arm of the turning couple, viz. the distance between this centre of effort and centre of ship's lateral resistance becoming less inclined; while this is inclined, there is a tendency to heel, which may sometimes be troublesome, especially in sailing-ships.

Stream-lines modify the velocity and the direction with which particles of water impinge on the rudder less perceptibly in screw-propelled than in sailing-ships. Another phenomenon may be noticed, viz. that a vessel or model moving in the direction of its length is, on stream-line principles, in a position of unstable equilibrium. She will always have a tendency to deviate on one side or the other—on which seems a matter of indifference; but this tendency will, when once exhibited, go on increasing until she turns broadside on to her original direction. In a sailing-vessel moving obliquely to the direction of the wind the relative position of the centre of effort of sail and of lateral resistance may oblige her to carry lee or weather helm according as she is ardent or slack. In any case the less helm a ship requires, the less is her way retarded, and the better she will sail.

I can only glance at the improvements which have been made in the forms of rudder; of these the most important, as far as screw-ships are concerned, is the pivot-balanced rudder, in which, by placing the axis of rotation at or near the centre of effort, very little power is required at the tiller or wheel to bring it over to any required angle. The most usual form is that fitted to the 'Bellerophon,' in which the proportion of the fore and aft part (determined by experiment) is as 1 to 2; when under steam the column of water driven backwards by the screw acts powerfully on each side and produces a strong turning power. When under sail the fore part is disconnected from the aft, and being fixed in the direction of the keel, becomes a stern-post. The means of still further increasing this stern-post or dead wood by a movable plane under the counters now fitting in screw-ships has already been adverted to

Lumley's rudder, in which the aft part is capable of being brought over by a system of chains or other suitable apparatus under the counter to a larger angle than the fore part, is based on a sound principle, intended by the inventor to imitate the action of a fish's tail. It is evident that by checking the velocity of the impinging stream a very considerable additional pressure is brought to bear on the fore part, and thus the steering quality is much improved. It was formerly fitted in several of H.M. ships, but has been latterly discontinued in consequence of the rusting and corrosion of the chains and self-acting machinery under water. Chaplin's rudder, consisting of two plane surfaces fitted in the counter, inclined at about an angle of 30 deg., the outer edges flush with the counter when not required, but let down by suitable machinery when wanted for use, was tried on board H.M. ship 'Sultan' and immediately condemned as useless, needs no further comment. Other forms which have not been received at all favourable need no description.

Another form, however, invented by Mr. Gumpel, seems very promising. Its peculiarity is that the tiller-power applied in the ordinary way gives motion to a crank working on a vertical axis moving freely on the rudder-blade at or about the centre of water effort. The fore end of the blade is directed by a pintle moving in a fore-and-aft slot, so that it always remains in a line with the keel. When put hard over to an angle of 38 deg. 40 min. the crank is at right angles to the blade, which requires the length of the crank to be to the distance of the vertical axis from the fore edges as 4 to 5. The ratio of the forces required at the tiller of this rudder to that of the ordinary rudder, to keep it at angles of 5 deg., 10 deg., 15 deg., up to 35 deg., and 38 deg. 40 min., is given in the following Table, and is independent of the laws of resistance.

Angles at which rudder is held.	**Ratio of forces at the tiller in Gumpel's and common rudder.**
0°	·80
5°	·78
10°	·74
15°	·66
20°	·56
25°	·44
30°	·29
35°	·13
38° 40′	·00

The ratio of work required to put over the two rudders respectively to angle 38 deg. 40 min. is found to be four tenths if the resistance is supposed to vary as the square of the line of inclination, and five tenths if (as is more correctly assumed) it vary simply as the sine of this angle.

The value of this rudder is manifest, as when the angle increases the relative force diminishes considerably; and after about 26 deg. the absolute force diminishes, until at 38 deg. 40 min. it vanishes; and it is for the higher angles that the difficulty of putting the common rudder over is most felt.

APPENDIX.

On the Effect of Heat in altering the Molecular Structure of Steel. By W. F. Barrett, *F.R.S.E., Professor of Physics, Royal College of Science for Ireland.*

If a wire of steel of any thickness be heated, by any means, at a certain critical temperature and for a certain length of time, the wire ceases to expand, although heat be continuously poured in. During this period also the wire does not sensibly increase in temperature. The length of time this abnormal condition lasts varies with the thickness of the wire and the rapidity with which it can be heated through its mass.

Rods of steel from two to three tenths of an inch in diameter cease to expand for five seconds when the wire is heated in a powerful combustion-furnace. This change takes place as the wire begins to glow with a red heat and after it has expanded one hundredth of its total length. The temperature of the critical point is a little over the melting-point of antimony, but under that of silver. The heating being continued, the elongation of the wire is resumed till the wire glows with the full heat it can attain from the source; it then ceases to expand, and no further change is noticed till the heat is cut off. When this is done, the wire begins to cool down regularly, till it has reached the critical point at which the change took place on heating. Here a second and reverse change occurs. This is the disturbance first noticed some time ago by Mr. Gore, and which he believed was confined to the cooling of steel wires and of wires of small diameter This, however, the author has found not to be the case. Hence it appears that, at a certain critical temperature, the molecular structure of steel changes. The specific heat of the metal doubtless increases at this point, and the heat that is rendered latent is again given out at the corresponding temperature during cooling, when both the molecular structure and the specific heat of steel pass into their normal state at the temperature of the air.

The molecular disturbances during the *cooling* of steel wires are thus exceedingly remarkable, and may be summarized as follows:—

1st. At the critical temperature these wires undergo a momentary and considerable elongation, the amount mainly depending on the strain to which the wire is subjected. When wires of gradually increasing thickness are used, the amount of the elongation diminishes; but the duration increases considerably, lasting fifteen seconds with a steel wire from two to three tenths of an inch in diameter.

2nd. At the moment that the expansion occurs, an actual increase in temperature takes place sufficiently large to cause the wire to glow again with a red heat. It is very curious that this *after-glow* has not been noticed long ago, for it is a very conspicuous object in steel wires that have been raised to a white heat and allowed to cool.

3rd. The molecular change taking place during cooling is accompanied by a series of ticking sounds like those produced by scraping the edge of a metal plate with a jagged knife.

4th. But the most interesting point remains to be noticed. This is the fact that the critical temperature is precisely that at which iron and steel resume their properties as magnetic metals, a property they had lost when at a white heat.

5th. Further, the molecular changes already noticed are coincident with the alteration in the thermoelectric properties of iron discovered by Prof. Tait. It appears, therefore, that this remarkable critical temperature of steel is intimately connected with many different and important phenomena. Some light may thus be obtained on the inner structure of a magnet and other obscure phenomena. The author stated that he had brought forward the foregoing points in a research that is now in progress, in the hope that he might have the benefit of suggestions from the eminent physicists that were present.

On Mechanical Self-Registering Apparatus for Barometer, Thermometer, Rain- and Wind-Gauges. By N. LOWENTHAL LONSDALE.

The author described (1) a glass pen, of the form of the Würtemberg siphon, filled with clear lithographic ink, and marking on a prepared zinc plate or cylinder, from which might be printed zincographically copies for distribution and comparison; (2) the gearing, the "tape" connexion instead of rack and pinion; and (3) two sensitive thermometers—one an iron tube 56 inches long (closed at one end), filled with mercury, and an iron piston ground in at the open end: the piston has a play of one inch between the freezing- and boiling-points; but by means of his gearing this inch can be augmented *ad libitum*, and in connexion with the writing-apparatus would mark any fraction of Fahrenheit's degree. The other thermometer is a hammered or drawn zinc rod, 13 feet 6 inches long. These thermometers being fixed in the open air move an axis which penetrates the wall (or a pane of glass); and fixed on the other end, *in the room*, is an index, as also the well-balanced registering-apparatus.

Rain and velocity of wind are indicated by a governor and the above-mentioned gearing; and the direction of wind by an arm, in connexion with the vane-shaft, revolving round a zinc cylinder.

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CONTENTS:—Proceedings of the Meeting;—John Taylor, on Mineral Veins;—Dr. Lindley, on the Philosophy of Botany;—Dr. Henry, on the Physiology of the Nervous System;—P. Barlow, on the Strength of Materials;—S. H. Christie, on the Magnetism of the Earth;—Rev. J. Challis, on the Analytical Theory of Hydrostatics and Hydrodynamics;—G. Rennie, on Hydraulics as a Branch of Engineering, Part I.;—Rev. G. Peacock, on certain Branches of Analysis.

Together with papers on Mathematics and Physics, Philosophical Instruments and Mechanical Arts, Natural History, Anatomy, Physiology, and History of Science.

PROCEEDINGS OF THE FOURTH MEETING, at Edinburgh, 1834, *Published at* 15*s.*

CONTENTS:—H. G. Rogers, on the Geology of North America;—Dr. C. Henry, on the Laws of Contagion;—Prof. Clark, on Animal Physiology;—Rev. L. Jenyns, on Zoology;—

Rev. J. Challis, on Capillary Attraction;—Prof. Lloyd, on Physical Optics;—G. Rennie, on Hydraulics, Part II.

Together with the Transactions of the Sections, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FIFTH MEETING, at Dublin, 1835, *Published at* 13*s*. 6*d*.

CONTENTS:—Rev. W. Whewell, on the Recent Progress and Present Condition of the Mathematical Theories of Electricity, Magnetism, and Heat; — A. Quetelet, Aperçu de l'Etat actuel des Sciences Mathématiques chez les Belges;—Capt. E. Sabine, on the Phenomena of Terrestrial Magnetism.

Together with the Transactions of the Sections, Prof. Sir W. Hamilton's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE SIXTH MEETING, at Bristol, 1836, *Published at* 12*s*.

CONTENTS:—Prof. Daubeny, on the Present State of our Knowledge with respect to Mineral and Thermal Waters;—Major E. Sabine, on the Direction and Intensity of the Terrestrial Magnetic Force in Scotland;—J. Richardson, on North American Zoology;—Rev. J. Challis, on the Mathematical Theory of Fluids;—J. T. Mackay, a Comparative View of the more remarkable Plants which characterize the neighbourhood of Dublin and Edinburgh, and the South-west of Scotland, &c;—J. T. Mackay, Comparative Geographical Notices of the more remarkable Plants which characterize Scotland and Ireland;—Report of the London Sub-Committee of the Medical Section on the Motions and Sounds of the Heart;—Second Report of the Dublin Sub-Committee on the Motions and Sounds of the Heart;—Report of the Dublin Committee on the Pathology of the Brain and Nervous System;—J. W. Lubbock, Account of the Recent Discussions of Observations of the Tides;—Rev. B. Powell, on determining the Refractive Indices for the Standard Rays of the Solar Spectrum in various media;—Dr. Hodgkin, on the Communication between the Arteries and Absorbents;—Prof. Phillips, Report of Experiments on Subterranean Temperature;—Prof. Hamilton, on the Validity of a Method recently proposed by G. B. Jerrard, for Transforming and Resolving Equations of Elevated Degrees.

Together with the Transactions of the Sections, Prof. Daubeny's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE SEVENTH MEETING, at Liverpool, 1837, *Published at* 16*s*. 6*d*.

CONTENTS:—Major E. Sabine, on the Variations of the Magnetic Intensity observed at different points of the Earth's Surface;—Rev. W. Taylor, on the various modes of Printing for the Use of the Blind;—J. W. Lubbock, on the Discussions of Observations of the Tides;—Prof. T. Thomson, on the Difference between the Composition of Cast Iron produced by the Cold and Hot Blast;—Rev. T. R. Robinson, on the Determination of the Constant of Nutation by the Greenwich Observations;—R. W. Fox, Experiments on the Electricity of Metallic Veins, and the Temperature of Mines;—Provisional Report of the Committee of the Medical Section of the British Association, appointed to investigate the Composition of Secretions, and the Organs producing them;—Dr. G. O. Rees, Report from the Committee for inquiring into the Analysis of the Glands, &c. of the Human Body;—Second Report of the London Sub-Committee of the British Association Medical Section, on the Motions and Sounds of the Heart;—Prof. Johnston, on the Present State of our Knowledge in regard to Dimorphous Bodies;—Lt.-Col. Sykes, on the Statistics of the Four Collectorates of Dukhun, under the British Government;—E. Hodgkinson, on the relative Strength and other Mechanical Properties of Iron obtained from the Hot and Cold Blast;—W. Fairbairn, on the Strength and other Properties of Iron obtained from the Hot and Cold Blast;—Sir J. Robison and J. S. Russell, Report of the Committee on Waves;—Note by Major Sabine, being an Appendix to his Report on the Variations of the Magnetic Intensity observed at different Points of the Earth's Surface;—J. Yates, on the Growth of Plants under Glass, and without any free communication with the outward Air, on the Plan of Mr. N. J. Ward, of London.

Together with the Transactions of the Sections, Prof. Traill's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE EIGHTH MEETING, at Newcastle, 1838, *Published at* 15*s*.

CONTENTS:—Rev. W. Whewell, Account of a Level Line, measured from the Bristol Channel to the English Channel, by Mr. Bunt;—Report on the Discussions of Tides, prepared under the direction of the Rev. W. Whewell;—W. S. Harris, Account of the Progress and State of the Meteorological Observations at Plymouth;—Major E. Sabine, on the Magnetic Isoclinal and Isodynamic Lines in the British Islands;—D. Lardner, LL.D., on the Determination of the Mean Numerical Values of Railway Constants;—R. Mallet, First Report upon Experiments upon the Action of Sea and River Water upon Cast and Wrought Iron;—R. Mallet, on the Action of a Heat of 212° Fahr., when long continued, on Inorganic and Organic Substances.

Together with the Transactions of the Sections, Mr. Murchison's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE NINTH MEETING, at Birmingham, 1839, *Published at* 13*s*. 6*d*. (Out of Print.)

Contents:—Rev. B. Powell, Report on the Present State of our Knowledge of Refractive Indices, for the Standard Rays of the Solar Spectrum in different media;—Report on the Application of the Sum assigned for Tide Calculations to Rev. W. Whewell, in a Letter from T. G. Bunt, Esq.;—H. L. Pattinson, on some Galvanic Experiments to determine the Existence or Non-Existence of Electrical Currents among Stratified Rocks, particularly those of the Mountain Limestone formation, constituting the Lead Measures of Alton Moor;—Sir D. Brewster, Reports respecting the two series of Hourly Meteorological Observations kept in Scotland;—Report on the subject of a series of Resolutions adopted by the British Association at their Meeting in August 1838, at Newcastle;—R. Owen, Report on British Fossil Reptiles;—E. Forbes, Report on the Distribution of Pulmoniferous Mollusca in the British Isles;—W. S. Harris, Third Report on the Progress of the Hourly Meteorological Register at Plymouth Dockyard.

Together with the Transactions of the Sections, Rev. W. Vernon Harcourt's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TENTH MEETING, at Glasgow, 1840, *Published at* 15*s*. (Out of Print.)

Contents:—Rev. B. Powell, Report on the recent Progress of discovery relative to Radiant Heat, supplementary to a former Report on the same subject inserted in the first volume of the Reports of the British Association for the Advancement of Science;—J. D. Forbes, Supplementary Report on Meteorology;—W. S. Harris, Report on Prof. Whewell's Anemometer, now in operation at Plymouth;—Report on "The Motion and Sounds of the Heart," by the London Committee of the British Association, for 1839-40;—Prof. Schönbein, an Account of Researches in Electro-Chemistry;—R. Mallet, Second Report upon the Action of Air and Water, whether fresh or salt, clear or foul, and at various temperatures, upon Cast Iron, Wrought Iron and Steel;—R. W. Fox, Report on some Observations on Subterranean Temperature;—A. F. Osler, Report on the Observations recorded during the years 1837, 1838, 1839, and 1840, by the Self-registering Anemometer erected at the Philosophical Institution, Birmingham;—Sir D. Brewster, Report respecting the two Series of Hourly Meteorological Observations kept at Inverness and Kingussie, from Nov. 1st, 1838 to Nov. 1st, 1839;—W. Thompson, Report on the Fauna of Ireland: Div. *Vertebrata*;—C. J. B. Williams, M.D., Report of Experiments on the Physiology of the Lungs and Air-Tubes;—Rev. J. S. Henslow, Report of the Committee on the Preservation of Animal and Vegetable Substances.

Together with the Transactions of the Sections, Mr. Murchison and Major E. Sabine's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE ELEVENTH MEETING, at Plymouth, 1841, *Published at* 13*s*. 6*d*.

Contents:—Rev. P. Kelland, on the Present state of our Theoretical and Experimental Knowledge of the Laws of Conduction of Heat;—G. L. Roupell, M.D., Report on Poisons;—T. G. Bunt, Report on Discussions of Bristol Tides, under the direction of the Rev. W. Whewell;—D. Ross, Report on the Discussions of Leith Tide Observations, under the direction of the Rev. W. Whewell;—W. S. Harris, upon the working of Whewell's Anemometer at Plymouth during the past year;—Report of a Committee appointed for the purpose of superintending the scientific cooperation of the British Association in the System of Simultaneous Observations in Terrestrial Magnetism and Meteorology;—Reports of Committees appointed to provide Meteorological Instruments for the use of M. Agassiz and Mr. M'Cord;—Report of a Committee to superintend the reduction of Meteorological Observations;—Report of a Committee for revising the Nomenclature of the Stars;—Report of a Committee for obtaining Instruments and Registers to record Shocks and Earthquakes in Scotland and Ireland;—Report of a Committee on the Preservation of Vegetative Powers in Seeds;—Dr. Hodgkin, on Inquiries into the Races of Man;—Report of the Committee appointed to report how far the Desiderata in our knowledge of the Condition of the Upper Strata of the Atmosphere may be supplied by means of Ascents in Balloons or otherwise, to ascertain the probable expense of such Experiments, and to draw up Directions for Observers in such circumstances;—R. Owen, Report on British Fossil Reptiles;—Reports on the Determination of the Mean Value of Railway Constants;—D. Lardner, LL.D., Second and concluding Report on the Determination of the Mean Value of Railway Constants;—E. Woods, Report on Railway Constants;—Report of a Committee on the Construction of a Constant Indicator for Steam-Engines.

Together with the Transactions of the Sections, Prof. Whewell's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWELFTH MEETING, at Manchester, 1842, *Published at* 10*s*. 6*d*.

CONTENTS:—Report of the Committee appointed to conduct the cooperation of the British Association in the System of Simultaneous Magnetical and Meteorological Observations;—J. Richardson, M.D., Report on the present State of the Ichthyology of New Zealand;—W. S. Harris, Report on the Progress of Meteorological Observations at Plymouth;—Second Report of a Committee appointed to make Experiments on the Growth and Vitality of Seeds;—C. Vignoles, Report of the Committee on Railway Sections;—Report of the Committee for the Preservation of Animal and Vegetable Substances;—Lyon Playfair, M.D., Abstract of Prof. Liebig's Report on Organic Chemistry applied to Physiology and Pathology;—R. Owen, Report on the British Fossil Mammalia, Part I.;—R. Hunt, Researches on the Influence of Light on the Germination of Seeds and the Growth of Plants;—L. Agassiz, Report on the Fossil Fishes of the Devonian System or Old Red Sandstone;—W. Fairbairn, Appendix to a Report on the Strength and other Properties of Cast Iron obtained from the Hot and Cold Blast;—D. Milne, Report of the Committee for Registering Shocks of Earthquakes in Great Britain;—Report of a Committee on the construction of a Constant Indicator for Steam-Engines, and for the determination of the Velocity of the Piston of the Self-acting Engine at different periods of the Stroke;—J. S. Russell, Report of a Committee on the Form of Ships;—Report of a Committee appointed "to consider of the Rules by which the Nomenclature of Zoology may be established on a uniform and permanent basis;"—Report of a Committee on the Vital Statistics of large Towns in Scotland;—Provisional Reports, and Notices of Progress in special Researches entrusted to Committees and Individuals.

Together with the Transactions of the Sections, Lord Francis Egerton's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTEENTH MEETING, at Cork, 1843, *Published at* 12*s*.

CONTENTS:—Robert Mallet, Third Report upon the Action of Air and Water, whether fresh or salt, clear or foul, and at Various Temperatures, upon Cast Iron, Wrought Iron, and Steel;—Report of the Committee appointed to conduct the Cooperation of the British Association in the System of Simultaneous Magnetical and Meteorological Observations;—Sir J. F. W. Herschel, Bart., Report of the Committee appointed for the Reduction of Meteorological Observations;—Report of the Committee appointed for Experiments on Steam-Engines;—Report of the Committee appointed to continue their Experiments on the Vitality of Seeds;—J. S. Russell, Report of a Series of Observations on the Tides of the Frith of Forth and the East Coast of Scotland;—J. S. Russell, Notice of a Report of the Committee on the Form of Ships;—J. Blake, Report on the Physiological Action of Medicines;—Report of the Committee on Zoological Nomenclature;—Report of the Committee for Registering the Shocks of Earthquakes, and making such Meteorological Observations as may appear to them desirable;—Report of the Committee for conducting Experiments with Captive Balloons;—Prof. Wheatstone, Appendix to the Report;—Report of the Committee for the Translation and Publication of Foreign Scientific Memoirs;—C. W. Peach, on the Habits of the Marine Testacea;—E. Forbes, Report on the Mollusca and Radiata of the Ægean Sea, and on their distribution, considered as bearing on Geology;—L. Agassiz, Synoptical Table of British Fossil Fishes, arranged in the order of the Geological Formations;—R. Owen, Report on the British Fossil Mammalia, Part II.;—E. W. Binney, Report on the excavation made at the junction of the Lower New Red Sandstone with the Coal Measures at Collyhurst;—W.

Thompson, Report on the Fauna of Ireland: Div. *Invertebrata*;—Provisional Reports, and Notices of Progress in Special Researches entrusted to Committees and Individuals.

Together with the Transactions of the Sections, Earl of Rosse's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FOURTEENTH MEETING, at York, 1844, *Published at £1.*

CONTENTS:—W. B. Carpenter, on the Microscopic Structure of Shells;—J. Alder and A. Hancock, Report on the British Nudibranchiate Mollusca;—R. Hunt, Researches on the Influence of Light on the Germination of Seeds and the Growth of Plants;—Report of a Committee appointed by the British Association in 1840, for revising the Nomenclature of the Stars;—Lt.-Col. Sabine, on the Meteorology of Toronto in Canada;—J. Blackwall, Report on some recent researches into the Structure, Functions, and Economy of the *Araneidea* made in Great Britain;—Earl of Rosse, on the Construction of large Reflecting Telescopes;—Rev. W. V. Harcourt, Report on a Gas-furnace for Experiments on Vitrifaction and other Applications of High Heat in the Laboratory;—Report of the Committee for Registering Earthquake Shocks in Scotland;—Report of a Committee for Experiments on Steam-Engines;—Report of the Committee to investigate the Varieties of the Human Race;—Fourth Report of a Committee appointed to continue their Experiments on the Vitality of Seeds,—W. Fairbairn, on the Consumption of Fuel and the Prevention of Smoke;—F. Ronalds, Report concerning the Observatory of the British Association at Kew;—Sixth Report of the Committee appointed to conduct the Cooperation of the British Association in the System of Simultaneous Magnetical and Meteorological Observations;—Prof. Forchhammer on the influence of Fucoidal Plants upon the Formations of the Earth, on Metamorphism in general, and particularly the Metamorphosis of the Scandinavian Alum Slate;—H. E. Strickland, Report on the recent Progress and Present State of Ornithology;—T. Oldham, Report of Committee appointed to conduct Observations on Subterranean Temperature in Ireland;—Prof. Owen, Report on the Extinct Mammals of Australia, with descriptions of certain Fossils indicative of the former existence in that continent of large Marsupial Representatives of the Order Pachydermata;—W. S. Harris, Report on the working of Whewell and Osler's Anemometers at Plymouth, for the years 1841, 1842, 1843;—W. R. Birt, Report on Atmospheric Waves;—L. Agassiz, Rapport sur les Poissons Fossiles de l'Argile de Londres, with translation;—J. S. Russell, Report on Waves;—Provisional Reports, and Notices of Progress in Special Researches entrusted to Committees and Individuals.

Together with the Transactions of the Sections, Dean of Ely's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FIFTEENTH MEETING, at Cambridge, 1845, *Published at 12s.*

CONTENTS:—Seventh Report of a Committee appointed to conduct the Cooperation of the British Association in the System of Simultaneous Magnetical and Meteorological Observations;—Lt.-Col. Sabine, on some points in the Meteorology of Bombay;—J. Blake, Report on the Physiological Actions of Medicines;—Dr. Von Boguslawski, on the Comet of 1843;—R. Hunt, Report on the Actinograph;—Prof. Schönbein, on Ozone;—Prof. Erman, on the Influence of Friction upon Thermo-Electricity;—Baron Senftenberg, on the Self-Registering Meteorological Instruments employed in the Observatory at Senftenberg;—W. R. Birt, Second Report on Atmospheric Waves;—G. R. Porter, on the Progress and Present Extent of Savings' Banks in the United Kingdom;—Prof. Bunsen and Dr. Playfair, Report on the Gases evolved from Iron Furnaces, with reference to the Theory of Smelting of Iron;—Dr. Richardson, Report on the Ichthyology of the Seas of China and Japan;—Report of the Committee on the Registration of Periodical Phenomena of Animals and Vegetables;—Fifth Report of the Committee on the Vitality of Seeds;—Appendix, &c.

Together with the Transactions of the Sections, Sir J. F. W. Herschel's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE SIXTEENTH MEETING, at Southampton, 1846, *Published at 15s.*

CONTENTS:—G. G. Stokes, Report on Recent Researches in Hydrodynamics;—Sixth Report of the Committee on the Vitality of Seeds;—Dr. Schunck, on the Colouring Matters of Madder;—J. Blake, on the Physiological Action of Medicines;—R. Hunt, Report on the Actinograph;—R. Hunt, Notices on the Influence of Light on the Growth of Plants;—R. L. Ellis, on the Recent Progress of Analysis;—Prof. Forchhammer, on Comparative Analytical

Researches on Sea Water;—A. Erman, on the Calculation of the Gaussian Constants for 1829;—G. R. Porter, on the Progress, present Amount, and probable future Condition of the Iron Manufacture in Great Britain;—W. R. Birt, Third Report on Atmospheric Waves;—Prof. Owen, Report on the Archetype and Homologies of the Vertebrate Skeleton;—J. Phillips, on Anemometry;—J. Percy, M.D., Report on the Crystalline Flags;—Addenda to Mr. Birt's Report on Atmospheric Waves.

Together with the Transactions of the Sections, Sir R. I. Murchison's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE SEVENTEENTH MEETING, at Oxford, 1847, *Published at* 18*s.*

CONTENTS:—Prof. Langberg, on the Specific Gravity of Sulphuric Acid at different degrees of dilution, and on the relation which exists between the Development of Heat and the coincident contraction of Volume in Sulphuric Acid when mixed with Water;—R. Hunt, Researches on the Influence of the Solar Rays on the Growth of Plants;—R. Mallet, on the Facts of Earthquake Phenomena;—Prof. Nilsson, on the Primitive Inhabitants of Scandinavia;—W. Hopkins, Report on the Geological Theories of Elevation and Earthquakes;—Dr. W. B. Carpenter, Report on the Microscopic Structure of Shells;—Rev. W. Whewell and Sir James C. Ross, Report upon the Recommendation of an Expedition for the purpose of completing our knowledge of the Tides;—Dr. Schunck, on Colouring Matters;—Seventh Report of the Committee on the Vitality of Seeds;—J. Glynn, on the Turbine or Horizontal Water-Wheel of France and Germany;—Dr. R. G. Latham, on the present state and recent progress of Ethnographical Philology;—Dr. J. C. Prichard, on the various methods of Research which contribute to the Advancement of Ethnology, and of the relations of that Science to other branches of Knowledge;—Dr. C. C. J. Bunsen, on the results of the recent Egyptian researches in reference to Asiatic and African Ethnology, and the Classification of Languages;—Dr. C. Meyer, on the Importance of the Study of the Celtic Language as exhibited by the Modern Celtic Dialects still extant;—Dr. Max Müller, on the Relation of the Bengali to the Arian and Aboriginal Languages of India;—W. R. Birt, Fourth Report on Atmospheric Waves;—Prof. W. H. Dove, Temperature Tables, with Introductory Remarks by Lieut.-Col. E. Sabine;—A. Erman and H. Petersen, Third Report on the Calculation of the Gaussian Constants for 1829.

Together with the Transactions of the Sections, Sir Robert Harry Inglis's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE EIGHTEENTH MEETING, at Swansea, 1848, *Published at* 9*s.*

CONTENTS:—Rev. Prof. Powell, A Catalogue of Observations of Luminous Meteors;—J. Glynn on Water-pressure Engines;—R. A. Smith, on the Air and Water of Towns;—Eighth Report of Committee on the Growth and Vitality of Seeds;—W. R. Birt, Fifth Report on Atmospheric Waves;—E. Schunck, on Colouring Matters;—J. P. Budd, on the advantageous use made of the gaseous escape from the Blast Furnaces at the Ystalyfera Iron Works;—R. Hunt, Report of progress in the investigation of the Action of Carbonic Acid on the Growth of Plants allied to those of the Coal Formations;—Prof. H. W. Dove, Supplement to the Temperature Tables printed in the Report of the British Association for 1847;—Remarks by Prof. Dove on his recently constructed Maps of the Monthly Isothermal Lines of the Globe, and on some of the principal Conclusions in regard to Climatology deducible from them; with an introductory Notice by Lt.-Col. E. Sabine;—Dr. Daubeny, on the progress of the investigation on the Influence of Carbonic Acid on the Growth of Ferns;—J. Phillips, Notice of further progress in Anemometrical Researches;—Mr. Mallet's Letter to the Assistant-General Secretary;—A. Erman, Second Report on the Gaussian Constants;—Report of a Committee relative to the expediency of recommending the continuance of the Toronto Magnetical and Meteorological Observatory until December 1850.

Together with the Transactions of the Sections, the Marquis of Northampton's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE NINETEENTH MEETING, at Birmingham, 1849, *Published at* 10*s.*

CONTENTS:—Rev. Prof. Powell, A Catalogue of Observations of Luminous Meteors;—Earl of Rosse, Notice of Nebulæ lately observed in the Six-feet Reflector;—Prof. Daubeny, on the Influence of Carbonic Acid Gas on the health of Plants, especially of those allied to the Fossil Remains found in the Coal Formation;—Dr. Andrews, Report on the Heat of Combination;—Report of the Committee on the Registration of the Periodic Phenomena of Plants and

Animals;—Ninth Report of Committee on Experiments on the Growth and Vitality of Seeds;—F. Ronalds, Report concerning the Observatory of the British Association at Kew, from Aug. 9, 1848 to Sept. 12, 1849;—R. Mallet, Report on the Experimental Inquiry on Railway Bar Corrosion;—W. R. Birt, Report on the Discussion of the Electrical Observations at Kew.

Together with the Transactions of the Sections, the Rev. T. R. Robinson's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTIETH MEETING, at Edinburgh, 1850, *Published at 15s.* (Out of Print.)

CONTENTS:—R. Mallet, First Report on the Facts of Earthquake Phenomena;—Rev. Prof. Powell, on Observations of Luminous Meteors;—Dr. T. Williams, on the Structure and History of the British Annelida;—T. C. Hunt, Results of Meteorological Observations taken at St. Michael's from the 1st of January, 1840 to the 31st of December, 1849;—R. Hunt, on the present State of our Knowledge of the Chemical Action of the Solar Radiations;—Tenth Report of Committee on Experiments on the Growth and Vitality of Seeds;—Major-Gen. Briggs, Report on the Aboriginal Tribes of India;—F. Ronalds, Report concerning the Observatory of the British Association at Kew;—E. Forbes, Report on the Investigation of British Marine Zoology by means of the Dredge;—R. MacAndrew, Notes on the Distribution and Range in depth of Mollusca and other Marine Animals, observed on the coasts of Spain, Portugal, Barbary, Malta, and Southern Italy in 1849,—Prof. Allman, on the Present State of our Knowledge of the Freshwater Polyzoa;—Registration of the Periodical Phenomena of Plants and Animals;—Suggestions to Astronomers for the Observation of the Total Eclipse of the Sun on July 28, 1851.

Together with the Transactions of the Sections, Sir David Brewster's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-FIRST MEETING, at Ipswich, 1851, *Published at 16s. 6d.*

CONTENTS:—Rev. Prof. Powell, on Observations of Luminous Meteors;—Eleventh Report of Committee on Experiments on the Growth and Vitality of Seeds;—Dr. J. Drew, on the Climate of Southampton;—Dr. R. A. Smith, on the Air and Water of Towns: Action of Porous Strata, Water and Organic Matter;—Report of the Committee appointed to consider the probable Effects in an Economical and Physical Point of View of the Destruction of Tropical Forests;—A. Henfrey, on the Reproduction and supposed Existence of Sexual Organs in the Higher Cryptogamous Plants;—Dr. Daubeny, on the Nomenclature of Organic Compounds,—Rev. Dr. Donaldson, on two unsolved Problems in Indo-German Philology;—Dr. T. Williams, Report on the British Annelida;—R. Mallet, Second Report on the Facts of Earthquake Phenomena;—Letter from Prof. Henry to Col. Sabine, on the System of Meteorological Observations proposed to be established in the United States;—Col. Sabine, Report on the Kew Magnetographs,—J. Welsh, Report on the Performance of his three Magnetographs during the Experimental Trial at the Kew Observatory;—F. Ronalds, Report concerning the Observatory of the British Association at Kew, from September 12, 1850 to July 31, 1851;—Ordnance Survey of Scotland.

Together with the Transactions of the Sections, Prof. Airy's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-SECOND MEETING, at Belfast, 1852, *Published at 15s.*

CONTENTS:—R. Mallet, Third Report on the Facts of Earthquake Phenomena;—Twelfth Report of Committee on Experiments on the Growth and Vitality of Seeds;—Rev. Prof. Powell, Report on Observations of Luminous Meteors, 1851–52;—Dr. Gladstone, on the Influence of the Solar Radiations on the Vital Powers of Plants;—A Manual of Ethnological Inquiry;—Col. Sykes, Mean Temperature of the Day, and Monthly Fall of Rain at 127 Stations under the Bengal Presidency;—Prof. J. D. Forbes, on Experiments on the Laws of the Conduction of Heat;—R. Hunt, on the Chemical Action of the Solar Radiations;—Dr. Hodges, on the Composition and Economy of the Flax Plant;—W. Thompson, on the Freshwater Fishes of Ulster;—W. Thompson, Supplementary Report on the Fauna of Ireland;—W. Wills, on the Meteorology of Birmingham;—J. Thomson, on the Vortex-Water-Wheel;—J. B. Lawes and Dr. Gilbert, on the Composition of Foods in relation to Respiration and the Feeding of Animals.

Together with the Transactions of the Sections, Colonel Sabine's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-THIRD MEETING, at Hull, 1853, *Published at* 10*s*. 6*d*.

CONTENTS:—Rev. Prof. Powell, Report on Observations of Luminous Meteors, 1852–53; —James Oldham, on the Physical Features of the Humber;—James Oldham, on the Rise, Progress, and Present Position of Steam Navigation in Hull;—William Fairbairn, Experimental Researches to determine the Strength of Locomotive Boilers, and the causes which lead to Explosion;—J. J. Sylvester, Provisional Report on the Theory of Determinants;—Professor Hodges, M.D., Report on the Gases evolved in Steeping Flax, and on the Composition and Economy of the Flax Plant;—Thirteenth Report of Committee on Experiments on the Growth and Vitality of Seeds;—Robert Hunt, on the Chemical Action of the Solar Radiations; —John P. Bell, M.D., Observations on the Character and Measurements of Degradation of the Yorkshire Coast; First Report of Committee on the Physical Character of the Moon's Surface, as compared with that of the Earth;—R. Mallet, Provisional Report on Earthquake Wave-Transits; and on Seismometrical Instruments;—William Fairbairn, on the Mechanical Properties of Metals as derived from repeated Meltings, exhibiting the maximum point of strength and the causes of deterioration;—Robert Mallet, Third Report on the Facts of Earthquake Phenomena (continued).

Together with the Transactions of the Sections, Mr. Hopkins's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-FOURTH MEETING, at Liverpool, 1854, *Published at* 18*s*.

CONTENTS:—R. Mallet, Third Report on the Facts of Earthquake Phenomena (continued); —Major-General Chesney, on the Construction and General Use of Efficient Life-Boats;—Rev. Prof. Powell, Third Report on the present State of our Knowledge of Radiant Heat;—Colonel Sabine, on some of the results obtained at the British Colonial Magnetic Observatories;—Colonel Portlock, Report of the Committee on Earthquakes, with their proceedings respecting Seismometers;—Dr. Gladstone, on the influence of the Solar Radiations on the Vital Powers of Plants, Part 2;—Rev. Prof. Powell, Report on Observations of Luminous Meteors, 1853–54; —Second Report of the Committee on the Physical Character of the Moon's Surface;—W. G. Armstrong, on the Application of Water-Pressure Machinery,—J. B. Lawes and Dr. Gilbert, on the Equivalency of Starch and Sugar in Food;—Archibald Smith, on the Deviations of the Compass in Wooden and Iron Ships;—Fourteenth Report of Committee on Experiments on the Growth and Vitality of Seeds.

Together with the Transactions of the Sections, the Earl of Harrowby's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-FIFTH MEETING, at Glasgow, 1855, *Published at* 15*s*.

CONTENTS:—T. Dobson, Report on the Relation between Explosions in Coal-Mines and Revolving Storms;—Dr. Gladstone, on the Influence of the Solar Radiations on the Vital Powers of Plants growing under different Atmospheric Conditions, Part 3;—C. Spence Bate, on the British Edriophthalma;—J. F. Bateman, on the present state of our knowledge on the Supply of Water to Towns;—Fifteenth Report of Committee on Experiments on the Growth and Vitality of Seeds;—Rev. Prof. Powell, Report on Observations of Luminous Meteors, 1854–55; —Report of Committee appointed to inquire into the best means of ascertaining those properties of Metals and effects of various modes of treating them which are of importance to the durability and efficiency of Artillery;—Rev. Prof. Henslow, Report on Typical Objects in Natural History;—A. Follett Osler, Account of the Self-Registering Anemometer and Rain-Gauge at the Liverpool Observatory;—Provisional Reports.

Together with the Transactions of the Sections, the Duke of Argyll's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-SIXTH MEETING, at Cheltenham, 1856, *Published at* 18*s*.

CONTENTS:—Report from the Committee appointed to investigate and report upon the effects produced upon the Channels of the Mersey by the alterations which within the last fifty years have been made in its Banks;—J. Thomson, Interim Report on progress in Researches on the Measurement of Water by Weir Boards;—Dredging Report, Frith of Clyde, 1856;—Rev. B. Powell, Report on Observations of Luminous Meteors, 1855–1856;—Prof. Bunsen and Dr. H. E. Roscoe, Photochemical Researches;—Rev. James Booth, on the Trigonometry of the Parabola, and the Geometrical Origin of Logarithms;—R. MacAndrew, Report on the Marine Testaceous Mollusca of the North-east Atlantic and Neighbouring Seas, and the physical conditions affecting their development;—P. P. Carpenter, Report on the present state of our knowledge with regard to the Mollusca of the West Coast of North America;—T. C. Eyton, Abstract of First Report on the Oyster Beds and Oysters of the British Shores;—Prof. Phillips, Report on Cleavage and Foliation in Rocks, and on the Theoretical Explanations of these Phenomena: Part I.;—Dr. T. Wright on the Stratigraphical Distribution of the Oolitic Echinodermata;—W. Fairbairn, on the Tensile Strength of Wrought Iron at various Temperatures;—C. Atherton, on Mercantile Steam Transport Economy;—J. S. Bowerbank, on the Vital Powers of the Spongiadæ;—Report of a Committee upon the Experiments conducted at Stormontfield, near Perth, for the artificial propagation of Salmon;—Provisional Report on the Measurement of Ships for Tonnage,—On Typical Forms of Minerals, Plants and Animals for Museums;—J. Thomson, Interim Report on Progress in Researches on the Measurement of Water by Weir Boards;—R. Mallet, on Observations with the Seismometer;—A. Cayley, on the Progress of Theoretical Dynamics;—Report of a Committee appointed to consider the formation of a Catalogue of Philosophical Memoirs.

Together with the Transactions of the Sections, Dr. Daubeny's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-SEVENTH MEETING, at Dublin, 1857, *Published at 15s.*

CONTENTS:—A. Cayley, Report on the Recent Progress of Theoretical Dynamics;—Sixteenth and final Report of Committee on Experiments on the Growth and Vitality of Seeds;—James Oldham, C.E., continuation of Report on Steam Navigation at Hull;—Report of a Committee on the Defects of the present methods of Measuring and Registering the Tonnage of Shipping, as also of Marine Engine-Power, and to frame more perfect rules, in order that a correct and uniform principle may be adopted to estimate the Actual Carrying Capabilities and Working-Power of Steam Ships;—Robert Were Fox, Report on the Temperature of some Deep Mines in Cornwall;—Dr. G. Plarr, De quelques Transformations de la Somme $\Sigma_{0}^{-\alpha} t\, \frac{\alpha^{t|+1}\beta^{t|+1}\delta^{t|+1}}{1^{t|+1}\gamma^{t|+1}\epsilon^{t|+1}}$, α étant entier négatif, et de quelques cas dans lesquels cette somme est exprimable par une combinaison de factorielles, la notation $\alpha^{t|+1}$ désignant le produit des t facteurs $\alpha\ (\alpha+1)\ (\alpha+2)$ &c....$(\alpha+t-1)$;—G. Dickie, M.D., Report on the Marine Zoology of Strangford Lough, County Down, and corresponding part of the Irish Channel;—Charles Atherton, Suggestions for Statistical Inquiry into the extent to which Mercantile Steam Transport Economy is affected by the Constructive Type of Shipping, as respects the Proportions of Length, Breadth, and Depth;—J. S. Bowerbank, Further Report on the Vitality of the Spongiadæ;—John P. Hodges, M.D., on Flax;—Major-General Sabine, Report of the Committee on the Magnetic Survey of Great Britain;—Rev. Baden Powell, Report on Observations of Luminous Meteors, 1856–57;—C. Vignoles, C.E., on the Adaptation of Suspension Bridges to sustain the passage of Railway Trains;—Professor W. A. Miller, M.D., on Electro-Chemistry;—John Simpson, R.N., Results of Thermometrical Observations made at the 'Plover's' Wintering-place, Point Barrow, latitude 71° 21′ N., long. 156° 17′ W., in 1852–54;—Charles James Hargreave, LL.D., on the Algebraic Couple; and on the Equivalents of Indeterminate Expressions;—Thomas Grubb, Report on the Improvement of Telescope and Equatorial Mountings;—Professor James Buckman, Report on the Experimental Plots in the Botanical Garden of the Royal Agricultural College at Cirencester;—William Fairbairn, on the Resistance of Tubes to Collapse;—George C. Hyndman, Report of the Proceedings of the Belfast Dredging Committee;—Peter W. Barlow, on the Mechanical Effect of combining Girders and Suspension Chains, and a Comparison of the Weight of Metal in Ordinary and Suspension Girders, to produce equal deflections with a given load;—J. Park Harrison, M.A., Evidences of Lunar Influence on Temperature;—Report on the Animal and Vegetable Products imported into Liverpool from the year 1851 to 1855 (inclusive);—Andrew Henderson, Report on the Statistics of Life-boats and Fishing-boats on the Coasts of the United Kingdom.

Together with the Transactions of the Sections, Rev. H. Lloyd's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-EIGHTH MEETING, at Leeds, September 1858, *Published at 20s.*

CONTENTS:—R. Mallet, Fourth Report upon the Facts and Theory of Earthquake Phenomena;—Rev. Prof. Powell, Report on Observations of Luminous Meteors, 1857–58;—R. H. Meade, on some Points in the Anatomy of the Araneidea or true Spiders, especially on the internal structure of their Spinning Organs;—W. Fairbairn, Report of the Committee on the Patent Laws;—S. Eddy, on the Lead Mining Districts of Yorkshire;—W. Fairbairn, on the

Collapse of Glass Globes and Cylinders;—Dr. E. Perceval Wright and Prof. J. Reay Greene, Report on the Marine Fauna of the South and West Coasts of Ireland;—Prof. J. Thomson, on Experiments on the Measurement of Water by Triangular Notches in Weir Boards;—Major-General Sabine, Report of the Committee on the Magnetic Survey of Great Britain;—Michael Connal and William Keddie, Report on Animal, Vegetable, and Mineral Substances imported from Foreign Countries into the Clyde (including the Ports of Glasgow, Greenock, and Port Glasgow) in the years 1853, 1854, 1855, 1856, and 1857;—Report of the Committee on Shipping Statistics;—Rev. H. Lloyd, D.D., Notice of the Instruments employed in the Magnetic Survey of Ireland, with some of the Results;—Prof. J. R. Kinahan, Report of Dublin Dredging Committee, appointed 1857-58;—Prof. J. R. Kinahan, Report on Crustacea of Dublin District;—Andrew Henderson, on River Steamers, their Form, Construction, and Fittings, with reference to the necessity for improving the present means of Shallow-Water Navigation on the Rivers of British India;—George C. Hyndman, Report of the Belfast Dredging Committee;—Appendix to Mr. Vignoles's paper "On the Adaptation of Suspension Bridges to sustain the passage of Railway Trains;"—Report of the Joint Committee of the Royal Society and the British Association, for procuring a continuance of the Magnetic and Meteorological Observatories;—R. Beckley, Description of a Self-recording Anemometer.

Together with the Transactions of the Sections, Prof. Owen's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE TWENTY-NINTH MEETING, at Aberdeen, September 1859, *Published at* 15*s*.

CONTENTS:—George C. Foster, Preliminary Report on the Recent Progress and Present State of Organic Chemistry;—Professor Buckman, Report on the Growth of Plants in the Garden of the Royal Agricultural College, Cirencester;—Dr. A. Voelcker, Report on Field Experiments and Laboratory Researches on the Constituents of Manures essential to cultivated Crops;—A. Thomson, Esq., of Banchory, Report on the Aberdeen Industrial Feeding Schools;—On the Upper Silurians of Lesmahago, Lanarkshire;—Alphonse Gages, Report on the Results obtained by the Mechanico-Chemical Examination of Rocks and Minerals;—William Fairbairn, Experiments to determine the Efficiency of Continuous and Self-acting Breaks for Railway Trains;—Professor J. R. Kinahan, Report of Dublin Bay Dredging Committee for 1858-59;—Rev. Baden Powell, Report on Observations of Luminous Meteors for 1858-59;—Professor Owen, Report on a Series of Skulls of various Tribes of Mankind inhabiting Nepal, collected, and presented to the British Museum, by Bryan H. Hodgson, Esq., late Resident in Nepal, &c. &c.;—Messrs. Maskelyne, Hadow, Hardwich, and Llewelyn, Report on the Present State of our Knowledge regarding the Photographic Image;—G. C. Hyndman, Report of the Belfast Dredging Committee for 1859;—James Oldham, Continuation of Report of the Progress of Steam Navigation at Hull;—Charles Atherton, Mercantile Steam Transport Economy as affected by the Consumption of Coals;—Warren de la Rue, Report on the present state of Celestial Photography in England;—Professor Owen, on the Orders of Fossil and Recent Reptilia, and their Distribution in Time;—Balfour Stewart, on some Results of the Magnetic Survey of Scotland in the years 1857 and 1858, undertaken, at the request of the British Association, by the late John Welsh, Esq., F.R.S.;—W. Fairbairn, The Patent Laws: Report of Committee on the Patent Laws;—J. Park Harrison, Lunar Influence on the Temperature of the Air;—Balfour Stewart, an Account of the Construction of the Self-recording Magnetographs at present in operation at the Kew Observatory of the British Association;—Prof. H. J. Stephen Smith, Report on the Theory of Numbers, Part I.;—Report of the Committee on Steamship performance;—Report of the Proceedings of the Balloon Committee of the British Association appointed at the Meeting at Leeds;—Prof. William K. Sullivan, Preliminary Report on the Solubility of Salts at Temperatures above 100° Cent., and on the Mutual Action of Salts in Solution.

Together with the Transactions of the Sections, Prince Albert's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTIETH MEETING, at Oxford, June and July 1860, *Published at* 15*s*.

CONTENTS:—James Glaisher, Report on Observations of Luminous Meteors, 1859-60;—J. R. Kinahan, Report of Dublin Bay Dredging Committee;—Rev. J. Anderson, Report on the Excavations in Dura Den;—Professor Buckman, Report on the Experimental Plots in the Botanical Garden of the Royal Agricultural College, Cirencester;—Rev. R. Walker, Report of the Committee on Balloon Ascents;—Prof. W. Thomson, Report of Committee appointed to prepare a Self-recording Atmospheric Electrometer for Kew, and Portable Apparatus for observing Atmospheric Electricity;—William Fairbairn, Experiments to determine the Effect of

Vibratory Action and long-continued Changes of Load upon Wrought-iron Girders;—R. P. Greg, Catalogue of Meteorites and Fireballs, from A.D. 2 to A.D. 1860;—Prof. H. J. S. Smith, Report on the Theory of Numbers, Part II.;—Vice-Admiral Moorsom, on the Performance of Steam-vessels, the Functions of the Screw, and the Relations of its Diameter and Pitch to the Form of the Vessel;—Rev. W. V. Harcourt, Report on the Effects of long-continued Heat, illustrative of Geological Phenomena;—Second Report of the Committee on Steamship Performance;—Interim Report on the Gauging of Water by Triangular Notches;—List of the British Marine Invertebrate Fauna.

Together with the Transactions of the Sections, Lord Wrottesley's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTY-FIRST MEETING, at Manchester, September 1861, *Published at £1.*

Contents:—James Glaisher, Report on Observations of Luminous Meteors;—Dr. E. Smith, Report on the Action of Prison Diet and Discipline on the Bodily Functions of Prisoners, Part I.;—Charles Atherton, on Freight as affected by Differences in the Dynamic Properties of Steamships;—Warren De la Rue, Report on the Progress of Celestial Photography since the Aberdeen Meeting;—B. Stewart, on the Theory of Exchanges, and its recent extension;—Drs. E. Schunck, R. Angus Smith, and H. E. Roscoe, on the Recent Progress and Present Condition of Manufacturing Chemistry in the South Lancashire District;—Dr. J. Hunt, on Ethno-Climatology; or, the Acclimatization of Man;—Prof. J. Thomson, on Experiments on the Gauging of Water by Triangular Notches;—Dr. A. Voelcker, Report on Field Experiments and Laboratory Researches on the Constituents of Manures essential to cultivated Crops;—Prof. H. Hennessy, Provisional Report on the Present State of our Knowledge respecting the Transmission of Sound-signals during Fogs at Sea;—Dr. P. L. Sclater and F. von Hochstetter, Report on the Present State of our Knowledge of the Birds of the Genus *Apteryx* living in New Zealand;—J. G. Jeffreys, Report of the Results of Deep-sea Dredging in Zetland, with a Notice of several Species of Mollusca new to Science or to the British Isles;—Prof. J. Phillips, Contributions to a Report on the Physical Aspect of the Moon;—W. R. Birt, Contribution to a Report on the Physical Aspect of the Moon;—Dr. Collingwood and Mr. Byerley, Preliminary Report of the Dredging Committee of the Mersey and Dee;—Third Report of the Committee on Steamship Performance;—J. G. Jeffreys, Preliminary Report on the Best Mode of preventing the Ravages of *Teredo* and other Animals in our Ships and Harbours;—R. Mallet, Report on the Experiments made at Holyhead to ascertain the Transit-Velocity of Waves, analogous to Earthquake Waves, through the local Rock Formations;—T. Dobson, on the Explosions in British Coal-Mines during the year 1859;—J. Oldham, Continuation of Report on Steam Navigation at Hull;—Professor G. Dickie, Brief Summary of a Report on the Flora of the North of Ireland;—Professor Owen, on the Psychical and Physical Characters of the Mincopies, or Natives of the Andaman Islands, and on the Relations thereby indicated to other Races of Mankind;—Colonel Sykes, Report of the Balloon Committee;—Major-General Sabine, Report on the Repetition of the Magnetic Survey of England;—Interim Report of the Committee for Dredging on the North and East Coasts of Scotland;—W. Fairbairn, on the Resistance of Iron Plates to Statical Pressure and the Force of Impact by Projectiles at High Velocities;—W. Fairbairn, Continuation of Report to determine the effect of Vibratory Action and long-continued Changes of Load upon Wrought-Iron Girders;—Report of the Committee on the Law of Patents;—Prof. H. J. S. Smith, Report on the Theory of Numbers, Part III.

Together with the Transactions of the Sections, Mr. Fairbairn's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTY-SECOND MEETING, at Cambridge, October 1862, *Published at £1.*

Contents:—James Glaisher, Report on Observations of Luminous Meteors, 1861–62;—G. B. Airy, on the Strains in the Interior of Beams;—Archibald Smith and F. J. Evans, Report on the three Reports of the Liverpool Compass Committee;—Report on Tidal Observations on the Humber;—T. Aston, on Rifled Guns and Projectiles adapted for Attacking Armour-plate Defences;—Extracts, relating to the Observatory at Kew, from a Report presented to the Portuguese Government, by Dr. J. A. de Souza;—H. T. Mennell, Report on the Dredging of the Northumberland Coast and Dogger Bank;—Dr. Cuthbert Collingwood, Report upon the best means of advancing Science through the agency of the Mercantile Marine;—Messrs. Williamson, Wheatstone, Thomson, Miller, Matthiessen, and Jenkin, Provisional Report on Standards of Electrical Resistance;—Preliminary Report of the Committee for investigating the Chemical and Mineralogical Composition of the Granites of Donegal;—Prof. H. Hennessy, on the Vertical Movements of the Atmosphere considered in connexion with Storms and Changes of Weather;—Report of Committee on the application of Gauss's General Theory of Terrestrial Magnetism to the Magnetic Variations;—Fleeming Jenkin, on Thermo-electric Currents in Circuits of one Metal;—W. Fairbairn, on the Mechanical Properties of Iron Projectiles at High Velocities;—A. Cayley, Report on the Progress of the Solution of certain Special Problems of Dynamics;—Prof. G. G. Stokes, Report on Double Refraction;—Fourth Report of the Committee on Steamship Performance;—G. J. Symons, on the Fall of Rain in the British Isles in 1860 and 1861;—J. Ball, on Thermometric Observations in the Alps;—J. G. Jeffreys, Report of the Committee for Dredging on the N. and E. Coasts of Scotland;—Report of the Committee on Technical and Scientific Evidence in Courts of Law;—James Glaisher, Account of Eight Balloon Ascents in 1862;—Prof. H. J. S. Smith, Report on the Theory of Numbers, Part IV.

Together with the Transactions of the Sections, the Rev. Prof. R. Willis's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTY-THIRD MEETING, at Newcastle-upon-Tyne, August and September 1863, *Published at £1 5s.*

Contents:—Report of the Committee on the Application of Gun-cotton to Warlike Purposes;—A. Matthiessen, Report on the Chemical Nature of Alloys;—Report of the Committee on the Chemical and Mineralogical Constitution of the Granites of Donegal, and on the Rocks associated with them;—J. G. Jeffreys, Report of the Committee appointed for Exploring the Coasts of Shetland by means of the Dredge;—G. D. Gibb, Report on the Physiological Effects of the Bromide of Ammonium;—C. K. Aken, on the Transmutation of Spectral Rays, Part I.;—Dr. Robinson, Report of the Committee on Fog Signals;—Report of the Committee on Standards of Electrical Resistance;—E. Smith, Abstract of Report by the Indian Government on the Foods used by the Free and Jail Populations in India;—A. Gages, Synthetical Researches on the Formation of Minerals, &c.;—R. Mallet, Preliminary Report on the Experimental Determination of the Temperatures of Volcanic Foci, and of the Temperature, State of Saturation, and Velocity of the issuing Gases and Vapours;—Report of the Committee on Observations of Luminous Meteors;—Fifth Report of the Committee on Steamship Performance;—G. J. Allman, Report on the Present State of our Knowledge of the Reproductive System in the Hydroida;—J. Glaisher, Account of Five Balloon Ascents made in 1863;—P. P. Carpenter, Supplementary Report on the Present State of our Knowledge with regard to the Mollusca of the West Coast of North America;—Professor Airy, Report on Steam-boiler Explosions;—C. W. Siemens, Observations on the Electrical Resistance and Electrification of some Insulating Materials under Pressures up to 300 Atmospheres;—C. M. Palmer, on the Construction of Iron Ships and the Progress of Iron Shipbuilding on the Tyne, Wear, and Tees;—Messrs. Richardson, Stevenson, and Clapham, on the Chemical Manufactures of the Northern Districts;—Messrs. Sopwith and Richardson, on the Local Manufacture of Lead, Copper, Zinc, Antimony, &c.;—Messrs. Daglish and Forster, on the Magnesian Limestone of Durham;—I. L. Bell, on the Manufacture of Iron in connexion with the Northumberland and Durham Coal-field;—T. Spencer, on the Manufacture of Steel in the Northern District;—H. J. S. Smith, Report on the Theory of Numbers, Part V.

Together with the Transactions of the Sections, Sir William Armstrong's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTY-FOURTH MEETING, at Bath, September 1864, *Published* at 18*s.*

Contents:—Report of the Committee for Observations of Luminous Meteors;—Report of the Committee on the best means of providing for a Uniformity of Weights and Measures;—T. S. Cobbold, Report of Experiments respecting the Development and Migration of the Entozoa;—B. W. Richardson, Report on the Physiological Action of Nitrite of Amyl;—J. Oldham, Report of the Committee on Tidal Observations;—G. S. Brady, Report on deep-sea Dredging on the Coasts of Northumberland and Durham in 1864;—J. Glaisher, Account of Nine Balloon Ascents made in 1863 and 1864;—J. G. Jeffreys, Further Report on Shetland Dredgings;—Report of the Committee on the Distribution of the Organic Remains of the North Staffordshire Coal-field;—Report of the Committee on Standards of Electrical Resistance;—G. J. Symons, on the Fall of Rain in the British Isles in 1862 and 1863;—W. Fairbairn, Preliminary Investigation of the Mechanical Properties of the proposed Atlantic Cable.

Together with the Transactions of the Sections, Sir Charles Lyell's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTY-FIFTH MEETING, at Birmingham, September 1865, *Published at £1 5s.*

Contents:—J. G. Jeffreys, Report on Dredging among the Channel Isles;—F. Buckland, Report on the Cultivation of Oysters by Natural and Artificial Methods;—Report of the Committee for exploring Kent's Cavern;—Report of the Committee on Zoological Nomenclature;—Report on the Distribution of the Organic Remains of the North Staffordshire Coal-field;—Report on the Marine Fauna and Flora of the South Coast of Devon and Cornwall;—Interim Report on the Resistance of Water to Floating and Immersed Bodies;—Report on Observations of Luminous Meteors;—Report on Dredging on the Coast of Aberdeenshire;—J. Glaisher, Account of Three Balloon Ascents;—Interim Report on the Transmission of Sound under Water;—G. J. Symons, on the Rainfall of the British Isles;—W. Fairbairn, on the Strength of Materials considered in relation to the Construction of Iron Ships; —Report of the Gun-Cotton Committee;—A. F. Osler, on the Horary and Diurnal Variations in the Direction and Motion of the Air at Wrottesley, Liverpool, and Birmingham;—B. W. Richardson, Second Report on the Physiological Action of certain of the Amyl Compounds; —Report on further Researches in the Lingula-flags of South Wales;—Report of the Lunar Committee for Mapping the Surface of the Moon;—Report on Standards of Electrical Resistance;—Report of the Committee appointed to communicate with the Russian Government respecting Magnetical Observations at Tiflis;—Appendix to Report on the Distribution of the Vertebrate Remains from the North Staffordshire Coal-field;—H. Woodward, First Report on the Structure and Classification of the Fossil Crustacea;—H. J. S. Smith, Report on the Theory of Numbers, Part VI.;—Report on the best means of providing for a Uniformity of Weights and Measures, with reference to the interests of Science;—A. G. Findlay, on the Bed of the Ocean;—Professor A. W. Williamson, on the Composition of Gases evolved by the Bath Spring called King's Bath.

Together with the Transactions of the Sections, Professor Phillips's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTY-SIXTH MEETING, at Nottingham, August 1866, *Published at £1 4s.*

Contents:—Second Report on Kent's Cavern, Devonshire;—A. Matthiessen, Preliminary Report on the Chemical Nature of Cast Iron;—Report on Observations of Luminous Meteors; —W. S. Mitchell, Report on the Alum Bay Leaf-bed;—Report on the Resistance of Water to Floating and Immersed Bodies;—Dr. Norris, Report on Muscular Irritability;—Dr. Richardson, Report on the Physiological Action of certain compounds of Amyl and Ethyl;—H. Woodward, Second Report on the Structure and Classification of the Fossil Crustacea;—Second Report on the "Menevian Group," and the other Formations at St. David's, Pembrokeshire;—J. G. Jeffreys, Report on Dredging among the Hebrides;—Rev. A. M. Norman, Report on the Coasts of the Hebrides, Part II.;—J. Alder, Notices of some Invertebrata, in connexion with Mr. Jeffreys's Report;—G. S. Brady, Report on the *Ostracoda* dredged amongst the Hebrides;—Report on Dredging in the Moray Firth;—Report on the Transmission of Sound-Signals under Water;—Report of the Lunar Committee;—Report of the Rainfall Committee;—Report on the best means of providing for a Uniformity of Weights and Measures, with reference to the Interests of Science;—J Glaisher, Account of Three Balloon Ascents;—Report on the Extinct Birds of the Mascarene Islands;—Report on the penetration of Iron-clad Ships by Steel Shot;—J. A. Wanklyn, Report on Isomerism among the Alcohols;—Report on Scientific Evidence in Courts of Law;—A. L. Adams, Second Report on Maltese Fossiliferous Caves, &c.

Together with the Transactions of the Sections, Mr. Grove's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTY-SEVENTH MEETING, at Dundee, September 1867, *Published at £1 6s.*

Contents:—Report of the Committee for Mapping the Surface of the Moon;—Third Report on Kent's Cavern, Devonshire;—On the present State of the Manufacture of Iron in Great Britain;—Third Report on the Structure and Classification of the Fossil Crustacea; —Report on the Physiological Action of the Methyl Compounds;—Preliminary Report on the Exploration of the Plant-Beds of North Greenland;—Report of the Steamship Performance Committee;—On the Meteorology of Port Louis in the Island of Mauritius;—On the Construction and Works of the Highland Railway;—Experimental Researches on the Mechanical Properties of Steel;—Report on the Marine Fauna and Flora of the South Coast of Devon and Cornwall;—Supplement to a Report on the Extinct Didine Birds of the Mascarene Islands;—Report on Observations of Luminous Meteors;—Fourth Report on Dredging among the Shetland Isles;—Preliminary Report on the Crustacea, &c., procured by the Shetland Dredging Committee in 1867;—Report on the Foraminifera obtained in the Shetland Seas;—Second Report of the Rainfall Committee;—Report on the best means of providing for a Uniformity of Weights and Measures, with reference to the Interests of Science;—Report on Standards of Electrical Resistance.

Together with the Transactions of the Sections, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTY-EIGHTH MEETING, at Norwich, August 1868, *Published at* £1 5*s*.

CONTENTS:—Report of the Lunar Committee;—Fourth Report on Kent's Cavern, Devonshire;—On Puddling Iron;—Fourth Report on the Structure and Classification of the Fossil Crustacea;—Report on British Fossil Corals;—Report on Spectroscopic Investigations of Animal Substances;—Report of Steamship Performance Committee;—Spectrum Analysis of the Heavenly Bodies;—On Stellar Spectrometry;—Report on the Physiological Action of the Methyl and allied Compounds;—Report on the Action of Mercury on the Biliary Secretion;—Last Report on Dredging among the Shetland Isles;—Reports on the Crustacea, &c., and on the Annelida and Foraminifera from the Shetland Dredgings;—Report on the Chemical Nature of Cast Iron, Part I.;—Interim Report on the Safety of Merchant Ships and their Passengers;—Report on Observations of Luminous Meteors;—Preliminary Report on Mineral Veins containing Organic Remains;—Report on the desirability of Explorations between India and China;—Report of Rainfall Committee;—Report on Synthetical Researches on Organic Acids;—Report on Uniformity of Weights and Measures:—Report of the Committee on Tidal Observations;—Report of the Committee on Underground Temperature;—Changes of the Moon's Surface;—Report on Polyatomic Cyanides.

Together with the Transactions of the Sections, Dr. Hooker's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE THIRTY-NINTH MEETING, at Exeter, August 1869, *Published* at £1 2*s*.

CONTENTS:—Report on the Plant-beds of North Greenland;—Report on the existing knowledge on the Stability, Propulsion, and Sea-going Qualities of Ships;—Report on Steam-boiler Explosions;—Preliminary Report on the Determination of the Gases existing in Solution in Well-waters;—The Pressure of Taxation on Real Property;—On the Chemical Reactions of Light discovered by Prof. Tyndall;—On Fossils obtained at Kiltorkan Quarry, co. Kilkenny;—Report of the Lunar Committee;—Report on the Chemical Nature of Cast Iron;—Report on the Marine Fauna and Flora of the south coast of Devon and Cornwall;—Report on the Practicability of establishing "a Close Time" for the Protection of Indigenous Animals;—Experimental Researches on the Mechanical Properties of Steel;—Second Report on British Fossil Corals;—Report of the Committee appointed to get cut and prepared Sections of Mountain-limestone Corals for Photographing;—Report on the rate of Increase of Underground Temperature;—Fifth Report on Kent's Cavern, Devonshire;—Report on the Connexion between Chemical Constitution and Physiological Action;—On Emission, Absorption, and Reflection of Obscure Heat;—Report on Observations of Luminous Meteors;—Report on Uniformity of Weights and Measures;—Report on the Treatment and Utilization of Sewage;—Supplement to Second Report of the Steamship-Performance Committee;—Report on Recent Progress in Elliptic and Hyperelliptic Functions;—Report on Mineral Veins in Carboniferous Limestone and their Organic Contents;—Notes on the Foraminifera of Mineral Veins and the Adjacent Strata;—Report of the Rainfall Committee;—Interim Report on the Laws of the Flow and Action of Water containing Solid Matter in Suspension;—Interim Report on Agricultural Machinery;—Report on the Physiological Action of Methyl and Allied Series;—On the Influence of Form considered in Relation to the Strength of Railway-axles and other portions of Machinery subjected to Rapid Alterations of Strain;—On the Penetration of Armour-plates with Long Shells of Large Capacity fired obliquely;—Report on Standards of Electrical Resistance.

Together with the Transactions of the Sections, Prof. Stokes's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FORTIETH MEETING, at Liverpool, September 1870, *Published at* 18*s*.

CONTENTS:—Report on Steam-boiler Explosions;—Report of the Committee on the Hæmatite Iron-ores of Great Britain and Ireland;—Report on the Sedimentary Deposits of the River Onny;—Report on the Chemical Nature of Cast Iron;—Report on the practicability of establishing "A Close Time" for the protection of Indigenous Animals;—Report on Standards of Electrical Resistance;—Sixth Report on Kent's Cavern;—Third Report on Underground Temperature;—Second Report of the Committee appointed to get cut and prepared Sections of Mountain-Limestone Corals;—Second Report on the Stability, Propulsion, and Sea-going Qualities of Ships;—Report on Earthquakes in Scotland;—Report on the Treatment and Utilization of Sewage;—Report on Observations of Luminous Meteors, 1869–70;—Report on Recent Progress in Elliptic and Hyperelliptic Functions;—Report on Tidal Observations;—On a new Steam-power Meter;—Report on the Action of the Methyl and Allied Series;—Report of the Rainfall Committee;—Report on the Heat generated in the Blood in the process of Arterialization;—Report on the best means of providing for Uniformity of Weights and Measures.

Together with the Transactions of the Sections, Prof. Huxley's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FORTY-FIRST MEETING, at Edinburgh, August 1871, *Published at* 16*s*.

CONTENTS:—Seventh Report on Kent's Cavern;—Fourth Report on Underground Temperature;—Report on Observations of Luminous Meteors, 1870–71;—Fifth Report on the Structure and Classification of the Fossil Crustacea;—Report for the purpose of urging on Her Majesty's Government the expediency of arranging and tabulating the results of the approaching Census in the three several parts of the United Kingdom in such a manner as to admit of ready and effective comparison;—Report for the purpose of Superintending the publication of Abstracts of Chemical papers;—Report of the Committee for discussing Observations of Lunar Objects suspected of change;—Second Provisional Report on the Thermal Conductivity of Metals;—Report on the Rainfall of the British Isles;—Third Report on the British Fossil Corals;—Report on the Heat generated in the Blood during the process of Arterialization;—Report of the Committee appointed to consider the subject of physiological Experimentation;—Report on the Physiological Action of Organic Chemical Compounds;—Report of the Committee appointed to get cut and prepared Sections of Mountain-Limestone Corals;—Second Report on Steam-Boiler Explosions;—Report on the Treatment and Utilization of Sewage;—Report on promoting the Foundation of Zoological Stations in different parts of the World;—Preliminary Report on the Thermal Equivalents of the Oxides of Chlorine;—Report on the practicability of establishing a "Close Time" for the protection of Indigenous Animals;—Report on Earthquakes in Scotland; Report on the best means of providing for a Uniformity of Weights and Measures;—Report on Tidal Observations.

Together with the Transactions of the Sections, Sir William Thomson's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FORTY-SECOND MEETING, at Brighton, August 1872, *Published at* £1 4*s*.

CONTENTS:—Report on the Gaussian Constants for the Year 1829;—Second Supplementary Report on the Extinct Birds of the Mascarene Islands;—Report of the Committee for Superintending the Monthly Reports of the Progress of Chemistry;—Report of the Committee on the best means of providing for a Uniformity of Weights and Measures;—Eighth Report on Kent's Cavern;—Report on promoting the Foundation of Zoological Stations in different parts of the World;—Fourth Report on the Fauna of South Devon;—Preliminary Report of the Committee appointed to Construct and Print Catalogues of Spectral Rays arranged upon a Scale of Wave-numbers;—Third Report on Steam-Boiler Explosions;—Report on Observations of Luminous Meteors, 1871–72;—Experiments on the Surface-friction experienced by a Plane moving through water;—Report of the Committee on the Antagonism between the Action of Active Substances;—Fifth Report on Underground Temperature;—Preliminary Report of the Committee on Siemens's Electrical-Resistance Pyrometer;—Fourth Report on the Treatment and Utilization of Sewage;—Interim Report of the Committee on Instruments for Measuring the Speed of Ships and Currents;—Report on the Rainfall of the British Isles;—Report of the Committee on a Geographical Exploration of the Country of Moab;—Sur l'élimination des Fonctions Arbitraires;—Report on the

Discovery of Fossils in certain remote parts of the North-western Highlands;—Report of the Committee on Earthquakes in Scotland;—Fourth Report on Carboniferous-Limestone Corals;—Report of the Committee to consider the mode in which new Inventions and Claims for Reward in respect of adopted Inventions are examined and dealt with by the different Departments of Government;—Report of the Committee for discussing Observations of Lunar Objects suspected of change;—Report on the Mollusca of Europe;—Report of the Committee for investigating the Chemical Constitution and Optical Properties of Essential Oils;—Report on the practicability of establishing a "Close Time" for the preservation of indigenous animals;—Sixth Report on the Structure and Classification of Fossil Crustacea;—Report of the Committee to organize an Expedition for observing the Solar Eclipse of Dec. 12, 1871; Preliminary Report of a Committee on Terato-embryological Inquiries;—Report on Recent Progress in Elliptic and Hyperelliptic Functions;—Report on Tidal Observations;—On the Brighton Waterworks;—On Amsler's Planimeter.

Together with the Transactions of the Sections, Dr. Carpenter's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FORTY-THIRD MEETING, at Bradford, September 1873, *Published at £1 5s.*

Contents:—Report of the Committee on Mathematical Tables;—Observations on the Application of Machinery to the cutting of Coal in Mines;—Concluding Report on the Maltese Fossil Elephants;—Report of the Committee for ascertaining the existence in different parts of the United Kingdom of any Erratic Blocks or Boulders;—Fourth Report on Earthquakes in Scotland;—Ninth Report on Kent's Cavern;—On the Flint and Chert Implements found in Kent's Cavern;—Report of the Committee for investigating the Chemical Constitution and Optical Properties of Essential Oils;—Report of inquiry into the Method of making Gold-assays;—Fifth Report on the Selection and Nomenclature of Dynamical and Electrical Units;—Report of the Committee on the Labyrinthodonts of the Coal-measures;—Report of the Committee to construct and print Catalogues of Spectral Rays;—Report of the Committee appointed to explore the Settle Caves;—Sixth Report on Underground Temperature;—Report on the Rainfall of the British Isles;—Seventh Report on Researches in Fossil Crustacea;—Report on Recent Progress in Elliptic and Hyperelliptic Functions;—Report on the desirability of establishing a "Close Time" for the preservation of indigenous animals;—Report on Luminous Meteors;—On the visibility of the dark side of Venus;—Report of the Committee for the foundation of Zoological Stations in different parts of the world;—Second Report of the Committee for collecting Fossils from North-western Scotland;—Fifth Report on the Treatment and Utilization of Sewage;—Report of the Committee on Monthly Reports of the Progress of Chemistry;—On the Bradford Waterworks;—Report on the possibility of Improving the Methods of Instruction in Elementary Geometry;—Interim Report of the Committee on Instruments for Measuring the Speed of Ships, &c.;—Report of the Committee for Determinating High Temperatures by means of the Refrangibility of Light, evolved by Fluid or Solid Substances;—On a periodicity of Cyclones and Rainfall in connexion with Sun-spot periodicity;—Fifth Report on the Structure of Carboniferous-Limestone Corals;—Report of the Committee on preparing and publishing brief forms of Instructions for Travellers, Ethnologists, &c.;—Preliminary Note from the Committee on the Influence of Forests on the Rainfall;—Report of Sub-Wealden Exploration Committee;—Report of the Committee on Machinery for obtaining a Record of the Roughness of the Sea and Measurement of Waves near shore;—Report on Science-Lectures and Organization;—Second Report on Science-Lectures and Organization.

Together with the Transactions of the Sections, Professor A. W. Williamson's Address, and Recommendations of the Association and its Committees.

PROCEEDINGS OF THE FORTY-FOURTH MEETING, at Belfast, August 1874, *Published at £1 5s.*

Contents:—Tenth Report on Kent's Cavern;—Report for investigating the Chemical Constitution and Optical Properties of Essential Oils;—Second Report of the Sub-Wealden Exploration Committee;—On the Recent Progress and Present State of Systematic Botany;—Report of the Committee for investigating the Nature of Intestinal Secretion;—Report of the Committee on the Teaching of Physics in Schools;—Preliminary Report for investigating Isomeric Cresols and their derivatives;—Third Report of the Committee for Collecting Fossils from localities in North-Western Scotland;—Report on the Rainfall of the British Isles;—On the Belfast Harbour;—Report of inquiry into the Method of making Gold-assays;—Report of a Committee on Experiments to determine the Thermal Conductivities of certain Rocks;—Second Report on the Exploration of the Settle Caves;—On the Industrial uses of the Upper Bann river;—Report of the Committee on the Structure and Classification of the Labyrinthodonts;—Second Report of the Committee for recording the position, height above the sea, lithological characters, size, and origin of the Erratic Blocks of England and Wales, &c.; Sixth Report on the Treatment and Utilization of Sewage;—Report on the Anthropological Notes and Queries for the use of Travellers;—On Cyclone and Rainfall Periodicities;—Fifth Report on Earthquakes in Scotland;—Report of the Committee to prepare and print Tables of Wave-numbers;—Report of the Committee for testing the new Pyrometer of Mr. Siemens;—Report to the Lords Commissioners of the Admiralty on Experiments for the Determination of the Frictional Resistance of Water on a Surface &c.;—Second Report for the Selection and Nomenclature of Dynamical and Electrical Units;—On Instruments for measuring the Speed of Ships;—Report of the Committee on the possibility of establishing a "Close time" for the Protection of Indigenous Animals;—Report of the Committee to inquire into the economic effects of Combinations of Labourers and Capitalists,—Preliminary Report on Dredging on the Coasts of Durham and North Yorkshire;—Report on Luminous Meteors;—Report on the best means of providing for a Uniformity of Weights and Measures.

Together with the Transactions of the Sections, Professor John Tyndall's Address, and Recommendations of the Association and its Committees.

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FOR

THE ADVANCEMENT OF SCIENCE.

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CORRECTED TO MAY 1876.

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1876.

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Notice of changes of Residence should be sent to the Assistant General Secretary, 22 Albemarle Street, London, W.

Year of Election.

Abbatt, Richard, F.R.A.S. Marlborough House, Woodberry Down, Stoke Newington, London, N.

1866. ‡Abbott, George J., United States Consul, Sheffield and Nottingham.

1863. *Abel, Frederick Augustus, F.R.S., F.C.S., Director of the Chemical Establishment of the War Department. Royal Arsenal, Woolwich, S.E.

1856. ‡Abercrombie, John, M.D. 13 Suffolk-square, Cheltenham.

1873. ‡*Abercrombie, William. 5 Fairmount, Bradford, Yorkshire.*

1863. *Abernethy, James. 4 Delahay-street, Westminster, London, S.W.

1873. ‡Abernethy, James. Ferry-hill, Aberdeen.

1860. ‡Abernethy, Robert. Ferry-hill, Aberdeen.

1873. *Abney, Captain, R.E., F.R.A.S., F.C.S. St. Margaret's, Rochester.

1854. ‡Abraham, John. 87 Bold-street, Liverpool.

1873. §Ackroyd, Samuel. Greaves-street, Little Horton, Bradford, Yorkshire.

1869. ‡Acland, Charles T. D. Sprydoncote, Exeter.

1873. *Acland, Rev. H. W. Loughton, Essex.

Acland, Henry W. D., M.A., M.D., LL.D., F.R.S., F.R.G.S., Regius Professor of Medicine in the University of Oxford. Broad-street, Oxford.

1860. ‡Acland, Sir Thomas Dyke, Bart., M.A., D.C.L., M.P. Sprydoncote, Exeter; and Athenæum Club, London, S.W.

Adair, John. 13 Merrion-square North, Dublin.

1872. ‡Adams, A. Leith, M.A., M.B., F.R.S., F.G.S., Professor of Zoology, Royal College of Science for Ireland. 18 Clarendon-gardens, Maida-vale, W.; and Junior United Service Club, Charles-street, St. James's, London, S.W.

Year of
Election.

*ADAMS, JOHN COUCH, M.A., LL.D., F.R.S., F.R.A.S., Director of the Observatory and Lowndsean Professor of Astronomy and Geometry in the University of Cambridge. The Observatory, Cambridge.
1871. §Adams, John R. 15 Old Jewry Chambers, London, E.C.
1869. *ADAMS, WILLIAM GRYLLS, M.A., F.R.S., F.G.S., F.C.P.S., Professor of Natural Philosophy and Astronomy in King's College, London. 9 Notting-hill-square, London, W.
1873. §Adams-Acton, John. Margutta House, 103 Marylebone-road, N.W.
ADDERLEY, The Right Hon. Sir CHARLES BOWYER, M.P. Hamshall Coleshill, Warwickshire.
Adelaide, Augustus Short, D.D., Bishop of. South Australia.
1860. *Adie, Patrick. Grove Cottage, Barnes, London, S.W.
1865. *Adkins, Henry. The Firs, Edgbaston, Birmingham.
1864. *Ainsworth, David. The Flosh, Cleator, Whitehaven.
1871. *Ainsworth, John Stirling. The Flosh, Cleator, Whitehaven.
Ainsworth, Peter. Smithills Hall, Bolton.
1842. *Ainsworth, Thomas. The Flosh, Cleator, Whitehaven.
1871. ‡Ainsworth, William M. The Flosh, Cleator, Whitehaven.
1859. ‡AIRLIE, The Right Hon. the Earl of, K.T. Holly Lodge, Campden Hill, London, W.; and Airlie Castle, Forfarshire.
AIRY, Sir GEORGE BIDDELL, K.C.B., M.A., LL.D., D.C.L., F.R.S., F.R.A.S., Astronomer Royal. The Royal Observatory, Greenwich, S.E.
1871. §Aitken, John. Darroch, Falkirk, N.B.
Akroyd, Edward. Bankfield, Halifax.
1862. ‡ALCOCK, Sir RUTHERFORD, K.C.B. The Athenæum Club, Pall Mall, London, S.W.
1861. ‡Alcock, Thomas, M.D. Side Brook, Salemoor, Manchester.
1872. *Alcock, Thomas, M.D. Oakfield, Ashton-on-Mersey, Manchester.
*Aldam, William. Frickley Hall, near Doncaster.
ALDERSON, Sir JAMES, M.A., M.D., D.C.L., F.R.S., Consulting Physician to St. Mary's Hospital. 17 Berkeley-square, London, W.
1857. ‡Aldridge, John, M.D. 20 Ranelagh-road, Dublin.
1859. ‡ALEXANDER, Major-General Sir JAMES EDWARD, C.B., K.C.L.S., F.R.A.S., F.R.G.S., F.R.S.E. Westerton, Bridge of Allan, N.B.
1873. ‡Alexander, Reginald, M.D. 13 Hallfield-road, Bradford, Yorkshire.
1858. ‡ALEXANDER, WILLIAM, M.D. Halifax.
1850. ‡Alexander, Rev. William Lindsay, D.D., F.R.S.E. Pinkieburn, Musselburgh, by Edinburgh.
1867. ‡Alison, George L. C. Dundee.
1863. ‡*Allan, Miss.*
1859. ‡Allan, Alexander. Scottish Central Railway, Perth.
1871. ‡Allan, G., C.E. 17 Leadenhall-street, London, E.C.
Allan, William.
1871. §ALLEN, ALFRED H., F.C.S. 1 Surrey-street, Sheffield.
1861. ‡Allen, Richard. Didsbury, near Manchester.
Allen, William. 50 Henry-street, Dublin.
1852. *ALLEN, WILLIAM J. C., Secretary to the Royal Belfast Academical Institution. Ulster Bank, Belfast.
1863. ‡Allhusen, C. Elswick Hall, Newcastle-on-Tyne.
*Allis, Thomas, F.L.S. Osbaldwick Hall, near York.
*ALLMAN, GEORGE J., M.D., F.R.S.L. & E., M.R.I.A., F.L.S., Emeritus Professor of Natural History in the University of Edinburgh. 21 Marlborough-road, London, N.W.; and Athenæum Club, London, S.W.

Year of
Election.

1875. §Alston, Edward R. 22A Dorset-street, Portman-square, London, W.
1873. §Ambler, John. North-park-road, Bradford, Yorkshire.
1850. ‡Anderson, Charles William. Cleadon, South Shields.
1850. ‡Anderson, John. 31 St. Bernard's-crescent, Edinburgh.
1874. ‡Anderson, John, J.P., F.G.S. Holywood, Belfast.
1859. ‡ANDERSON, PATRICK. 15 King-street, Dundee.
1875. §Anderson, Captain S., R.E. Junior United Service Club, Charles-street, St. James's, London, S.W.
1870. ‡Anderson, Thomas Darnley. West Dingle, Liverpool.
1853. **Anderson, William (Yr.). 2 Lennox-street, Edinburgh.*
*ANDREWS, THOMAS, M.D., LL.D., F.R.S., Hon. F.R.S.E., M.R.I.A., F.C.S., Vice-President and Professor of Chemistry, Queen's College, Belfast. (PRESIDENT DESIGNATE.) Queen's College, Belfast.
1857. ‡Andrews, William. The Hill, Monkstown, Co. Dublin.
1859. ‡Angus, John. Town House, Aberdeen.
*ANSTED, DAVID THOMAS, M.A., F.R.S., F.G.S., F.R.G.S. 4 Westminster Chambers, Westminster, S.W.; and Melton, Suffolk.
Anthony, John, M.D. Caius College, Cambridge.
APJOHN, JAMES, M.D., F.R.S., M.R.I.A., Professor of Mineralogy at Dublin University. South Hill, Blackrock, Co. Dublin.
1863. ‡Appleby, C. J. Emerson-street, Bankside, Southwark, London, S.E.
1870. ‡Archer, Francis, jun. 3 Brunswick-street, Liverpool.
1855. *ARCHER, Professor THOMAS C., F.R.S.E., Director of the Museum of Science and Art. West Newington House, Edinburgh.
1874. ‡Archer, William, F.R.S., M.R.I.A. St. Brendan's, Grosvenor-road East, Rathmines, Dublin.
1851. ‡ARGYLL, His Grace the Duke of, K.T., LL.D., F.R.S. L. & E., F.G.S. Argyll Lodge, Kensington, London, W.; and Inveraray, Argyleshire.
1865. ‡Armitage, J. W., M.D. 9 Huntriss-row, Scarborough.
1861. ‡Armitage, William. 7 Meal-street, Mosley-street, Manchester.
1867. *Armitstead, George. Errol Park, Errol, N.B.
1873. §Armstrong, Henry E., Ph.D., F.C.S. London Institution, Finsbury-circus, E.C.
1874. §Armstrong, James T., F.C.S. 17 The Willows, Breck-road, Liverpool.
Armstrong, Thomas. Higher Broughton, Manchester.
1857. *ARMSTRONG, Sir WILLIAM GEORGE, C.B., LL.D., D.C.L., F.R.S. 8 Great George-street, London, S.W.; and Jesmond Dene, Newcastle-upon-Tyne.
1868. ‡Arnold, Edward, F.C.S. Prince of Wales-road, Norwich.
1871. ‡Arnot, William, F.C.S. St. Margaret's, Kirkintilloch, N.B.
1870. §Arnott, Thomas Reid. Bramshill, Harlesden Green, N.W.
1853. *Arthur, Rev. William, M.A. Clapham Common, London, S.W.
1870. *Ash, Dr. T. Linnington. Holsworthy, North Devon.
1874. ‡Ashe, Isaac, M.B. District Asylum, Londonderry.
1873. §Ashton, John. Gorse Bank House, Windsor-road, Oldham.
1842. *Ashton, Thomas, M.D. 8 Royal Wells-terrace, Cheltenham.
Ashton, Thomas. Ford Bank, Didsbury, Manchester.
1866. ‡Ashwell, Henry. Mount-street, New Basford, Nottingham.
*Ashworth, Edmund. Egerton Hall, Bolton-le-Moors.
Ashworth, Henry. Turton, near Bolton.
1861. ‡Aspland, Alfred. Dukinfield, Ashton-under-Lyne.
Aspland, Algernon Sydney. Glamorgan House, Durdham Down, Bristol.
1875. *Aspland, W. G. Lanesfield, Clifton, Bristol.

Year of
Election.
1861. §Asquith, J. R. Infirmary-street, Leeds.
1861. ‡Aston, Thomas. 4 Elm-court, Temple, London, E.C.
1872. §Atchison, Arthur T. Rose-hill, Dorking.
1873. ‡Atchison, D. G. Tyersall Hall, Yorkshire.
1858. ‡Atherton, Charles. Sandover, Isle of Wight.
1866. ‡Atherton, J. H., F.C.S. Long-row, Nottingham.
1865. ‡Atkin, Alfred. Griffin's-hill, Birmingham.
1861. ‡Atkin, Eli. Newton Heath, Manchester.
1865. *ATKINSON, EDMUND, Ph.D., F.C.S. 8 The Terrace, York Town, Surrey.
1863. *Atkinson, G. Clayton. 21 Windsor-terrace, Newcastle-on-Tyne.
1858. *Atkinson, John Hastings. 14 East Parade, Leeds.
1842. *Atkinson, Joseph Beavington. Stratford House, 113 Abingdon-road, Kensington, London, W.
1861. ‡Atkinson, Rev. J. A. Longsight Rectory, near Manchester.
1858. Atkinson, William. Claremont, Southport.
1863. *ATTFIELD, Professor J., Ph.D., F.C.S. 17 Bloomsbury-square, London, W.C.
1860. *Austin-Gourlay, Rev. William E. C., M.A. Stoke Abbott Rectory, Beaminster, Dorset.
1865. *Avery, Thomas. Church-road, Edgbaston, Birmingham.
1867. ‡Avison, Thomas, F.S.A. Fulwood Park, Liverpool.
1853. *Ayrton, W. S., F.S.A. Cliffden, Saltburn-by-the-Sea.

*BABINGTON, CHARLES CARDALE, M.A., F.R.S., F.L.S., F.G.S., Professor of Botany in the University of Cambridge. 5 Brookside, Cambridge.
Bache, Rev. Samuel. 74 Beaufort-road, Edgbaston, Birmingham.
Backhouse, Edmund. Darlington.
Backhouse, Thomas James. Sunderland.
1863. ‡Backhouse, T. W. West Hendon House, Sunderland.
1870. §Bailey, Dr. F. J. 51 Grove-street, Liverpool.
1865. ‡Bailey, Samuel, F.G.S. The Peck, Walsall.
1855. ‡Bailey, William. Horseley Fields Chemical Works, Wolverhampton.
1866. ‡Baillon, Andrew. St. Mary's Gate, Nottingham.
1866. ‡Baillon, L. St. Mary's Gate, Nottingham.
1857. ‡BAILY, WILLIAM HELLIER, F.L.S., F.G.S., Acting Palæontologist to the Geological Survey of Ireland. 14 Hume-street; and Apsley Lodge, 92 Rathgar-road, Dublin.
1873. §Bain, James. 3 Park-terrace, Glasgow.
1865. ‡BAIN, Rev. W. J. Glenlark Villa, Leamington.
*Bainbridge, Robert Walton. Middleton House, Middleton-in-Teesdale, by Darlington.
*BAINES, EDWARD. Belgrave-mansions, Grosvenor-gardens, London S.W.; and St. Ann's-hill, Burley, Leeds.
1858. ‡Baines, Frederick. Burley, near Leeds.
1858. ‡Baines, T. Blackburn. 'Mercury' Office, Leeds.
1866. ‡Baker, Francis B. Sherwood-street, Nottingham.
1858. *Baker, Henry Granville. Bellevue, Horsforth, near Leeds.
1865. ‡Baker, James P. Wolverhampton.
1861. *Baker, John. Gatley-hill, Cheadle, Manchester.
1865. ‡Baker, Robert L. Barham House, Leamington.
1849. *Baker, William. 63 Gloucester-place, Hyde Park, London, W.
1863. §Baker, William. 6 Taptonville, Sheffield.
1875. *Baker, W. Mills. Stoke Bishop, near Bristol.
1875. §Baker, W. Proctor. Brislington, Bristol.

Year of Election.

1860. ‡Balding, James, M.R.C.S. Barkway, Royston, Hertfordshire.
1871. ‡Balfour, Francis Maitland. Trinity College, Cambridge.
1871. *Balfour, G. W. Whittinghame, Prestonkirk, Scotland.
1875. *Balfour, Isaac Bayley, D.Sc. 27 Inverleith-road, Edinburgh.
*BALFOUR, JOHN HUTTON, M.D., M.A., F.R.S. L. & E., F.L.S., Professor of Botany in the University of Edinburgh. 27 Inverleith-row, Edinburgh.
*BALL, JOHN, M.A., F.R.S., F.L.S., M.R.I.A. 10 Southwell-gardens, South Kensington, London, W.
1866. *BALL, ROBERT STAWELL, M.A., LL.D., F.R.S., Andrews Professor of Astronomy in the University of Dublin, and Royal Astronomer. The Observatory, Dunsink, Co. Dublin.
1863. ‡Ball, Thomas. Bramcote, Nottingham.
*Ball, William. Bruce-grove, Tottenham, London, N.; and Glen Rothay, near Ambleside, Westmoreland.
1870. ‡Balmain, William H., F.C.S. Spring Cottage, Great St. Helens, Lancashire.
1869. ‡Bamber, Henry K., F.C.S. 5 Westminster-chambers, Victoria-street, Westminster, S.W.
1874. *Bangay, Frederick Arthur. Cheadle, Cheshire.
1852. ‡Bangor, Viscount. Castleward, Co. Down, Ireland.
1870. ‡BANISTER, Rev. WILLIAM, B.A. St. James's Mount, Liverpool.
1861. ‡Bannerman, James Alexander. Limefield House, Higher Broughton, near Manchester.
1866. ‡Barber, John. Long-row, Nottingham.
1861. *Barbour, George. Kingslee, Farndon, Chester.
1859. ‡Barbour, George F. 11 George-square, Edinburgh.
*Barbour, Robert. Bolesworth Castle, Tattenhall, Chester.
1855. ‡Barclay, Andrew. Kilmarnock, Scotland.
Barclay, Charles, F.S.A., M.R.A.S. Bury-hill, Dorking.
1871. ‡Barclay, George. 17 Coates-crescent, Edinburgh.
Barclay, James. Catrine, Ayrshire.
1852. *Barclay, J. Gurney. 54 Lombard-street, London, E.C.
1860. *Barclay, Robert. High Leigh, Hoddesden, Herts.
1868. *Barclay, W. L. 54 Lombard-street, London, E.C.
1863. *Barford, James Gale, F.C.S. Wellington College, Wokingham, Berkshire.
1860. *Barker, Rev. Arthur Alcock, B.D. East Bridgford Rectory, Notts.
1857. ‡Barker, John, M.D., Curator of the Royal College of Surgeons of Ireland. Waterloo-road, Dublin.
1865. ‡Barker, Stephen. 30 Frederick-street, Edgbaston, Birmingham.
1870. ‡BARKLY, Sir HENRY, K.C.B., F.R.S., Governor of Cape Colony and Dependencies. Cape of Good Hope.
1873. ‡Barlow, Crawford, B.A. 2 Old Palace-yard, Westminster, S.W.
Barlow, Lieut.-Col. Maurice (14th Regt. of Foot). 5 Great George-street, Dublin.
Barlow, Peter. 5 Great George-street, Dublin.
1857. ‡BARLOW, PETER WILLIAM, F.R.S., F.G.S. 8 Eliott-place, Blackheath, London, S.E.
1873. ‡BARLOW, W. H., C.E., F.R.S. 2 Old Palace-yard, Westminster, S.W.
1861. *Barnard, Major R. Cary, F.L.S. Bartlow, Leckhampton, Cheltenham.
1868. §Barnes, Richard H. (Care of Messrs. Collyer, 4 Bedford-row, London, W.C.)
Barnes, Thomas Addison. 40 Chester-street, Wrexham.

Year of Election.

*Barnett, Richard, M.R.C.S. Alfred Villa, Leicester-street, Leamington.
1859. ‡Barr, Major-General, Bombay Army. Culter House, near Aberdeen. (Messrs. Forbes, Forbes & Co., 9 King William-street, London.)
1861. *Barr, William R., F.G.S. Fernside, Cheadle Hulme, Cheshire.
1860. ‡Barrett, T. B. High-street, Welshpool, Montgomery.
1872. *BARRETT, Professor W. F., F.R.S.E., M.R.I.A., F.C.S. Royal College of Science, Dublin.
1852. ‡Barrington, Edward. Fassaroe Bray, Co. Wicklow.
1874. ‡Barrington, R. M. Fassaroe, Bray, Co. Wicklow.
1874. §Barrington-Ward, Mark J., B.A., F.L.S., F.R.G.S. St. Winifred's, Lincoln.
1866. ‡Barron, William. Elvaston Nurseries, Borrowash, Derby.
1858. ‡BARRY, Rev. A., D.D., D.C.L., Principal of King's College, London, W.C.
1862. *Barry, Charles. 15 Pembridge-square, Bayswater, London, W.
1875. §Barry, John Wolfe. 23 Delahay-street, Westminster, S.W.
Barstow, Thomas. Garrow-hill, near York.
1858. *Bartholomew, Charles. Castle-hill House, Ealing, Middlesex, W.
1855. ‡Bartholomew, Hugh. New Gas-works, Glasgow.
1858. *Bartholomew, William Hamond. Ridgeway House, Cumberland-road, Headingley, Leeds.
1873. §Bartley, George C. T. Ealing, Middlesex.
1868. *Barton, Edward (27th Inniskillens). Clonelly, Ireland.
1857. ‡Barton, Folloit W. Clonelly, Co. Fermanagh.
1852. ‡Barton, James. Farndreg, Dundalk.
1864. ‡Bartrum, John S. 41 Gay-street, Bath.
1870. §BARUCHSON, ARNOLD. 19 The Boltons, South Kensington, London, W.
*Bashforth, Rev. Francis, B.D. Minting Vicarage, near Horncastle.
1861. ‡Bass, John H., F.G.S. 287 Camden-road, London, N.
1866. *BASSETT, HENRY. 44 St. Paul's-road, Camden-square, London, N.W.
1866. ‡Bassett, Richard. Pelham-street, Nottingham.
1869. ‡Bastard, S. S. Summerland-place, Exeter.
1871. ‡BASTIAN, H. CHARLTON, M.A., M.D., F.R.S., F.L.S., Professor of Pathological Anatomy at University College Hospital. 20 Queen Anne-street, London, W.
1848. ‡BATE, C. SPENCE, F.R.S., F.L.S. 8 Mulgrave-place, Plymouth.
1873. *Bateman, Daniel. Low Moor, near Bradford, Yorkshire.
1868. ‡Bateman, Frederick, M.D. Upper St. Giles's-street, Norwich.
BATEMAN, JAMES, M.A., F.R.S., F.L.S. 9 Hyde Park-gate South, London, W.
1842. *BATEMAN, JOHN FREDERIC, C.E., F.R.S., F.G.S. 16 Great George-street, London, S.W.
1864. ‡BATES, HENRY WALTER, Assist.-Sec. R.G.S., F.L.S. 1 Savile-row, London, W.
1852. ‡Bateson, Sir Robert, Bart. Belvoir Park, Belfast.
1851. ‡BATH AND WELLS, Lord ARTHUR HERVEY, Lord Bishop of. The Palace, Wells, Somerset.
1863. *Bathurst, Rev. W. H. Lydney Park, Gloucestershire.
1869. ‡Batten, John Winterbotham. 35 Palace-gardens-terrace, Kensington, London, S.W.
1863. §BAUERMAN, H., F.G.S. 22 Acre-lane, Brixton, London, S.W.
1861. ‡Baxendell, Joseph, F.R.A.S. 108 Stock-street, Manchester.
1867. ‡Baxter, Edward. Hazel Hall, Dundee.
1867. ‡Baxter, John B. Craig Tay House, Dundee.

Year of Election.
1867. ‡Baxter, William Edward, M.P. Ashcliffe, Dundee.
1868. ‡Bayes, William, M.D. 58 Brook-street, London, W.
1851. *Bayley, George. 2 Cowper's-court, Cornhill, London, E.C.
1866. †Bayley, Thomas. Lenton, Nottingham.
1854. ‡Baylis, C. O., M.D. 22 Devonshire-road, Claughton, Birkenhead.
Bayly, John. Seven Trees, Plymouth.
1875. *Bayly, Robert. Torr-grove, near, Plymouth.
1860. *BEALE, LIONEL S., M.D., F.R.S., Professor of Pathological Anatomy in King's College. 61 Grosvenor-street, London, W.
1861. §Bean, William. Alfreton, Derbyshire.
1872. ‡Beanes, Edward, F.C.S. Avon House, Dulwich Common, Surrey, S.E.
1870. ‡Beard, Rev. Charles. 13 South-hill-road, Toxteth Park, Liverpool.
*Beatson, William. Chemical Works, Rotherham.
1855. *Beaufort, W. Morris, F.R.G.S. Athenæum Club, Pall Mall, London, S.W.
1861. *Beaumont, Rev. Thomas George. Chelmondiston Rectory, Ipswich.
1871. *Beazley, Captain George G. Army and Navy Club, Pall Mall, London, S.W.
1859. *Beck, Joseph, F.R.A.S. 31 Cornhill, London, E.C.
1864. §Becker, Miss Lydia E. Whalley Range, Manchester.
1860. ‡BECKLES, SAMUEL H., F.R.S., F.G.S. 9 Grand-parade, St. Leonard's-on-Sea.
1866. ‡Beddard, James. Derby-road, Nottingham.
1870. §BEDDOE, JOHN, M.D., F.R S. Clifton, Bristol.
1873. ‡Behrens, Jacob. Springfield House, North-parade, Bradford.
1865. *BELAVENETZ, I., Captain of the Russian Imperial Navy, F.R.I.G.S., M.S.C.M.A., Superintendent of the Compass Observatory, Cronstadt. (Care of Messrs. Baring Brothers, Bishopsgate-street, London, E.C.)
1847. *BELCHER, Admiral Sir EDWARD, K.C.B., F.R.A.S., F.R.G.S. 13 Dorset-street, Portman-square, London, W.
1874. ‡Belcher, Richard Boswell. Blockley, Worcestershire.
1873. §Bell, A. P. Royal Exchange, Manchester.
1871. §Bell, Charles B. 6 Spring-bank, Hull.
Bell, Frederick John. Woodlands, near Maldon, Essex.
1859. ‡Bell, George. Windsor-buildings, Dumbarton.
1860. ‡Bell, Rev. George Charles, M.A. Christ's Hospital, London, E.C.
1855. ‡Bell, Capt. Henry. Chalfont Lodge, Cheltenham.
1862. *BELL, ISAAC LOWTHIAN, M.P., F.R.S., F.C.S., M.I.C.E. The Hall, Washington, Co. Durham.
1875. §Bell, James, F.C.S. The Laboratory, Somerset House, London, W.C.
1871. *Bell, J. Carter, F.C.S. Cheadle, Cheshire.
1853. ‡Bell, John Pearson, M.D. Waverley House, Hull.
1864. ‡Bell, R. Queen's College, Kingston, Canada.
BELL, THOMAS, F.R.S., F.L.S., F.G.S. The Wakes, Selborne, near Alton, Hants.
1863. *Bell, Thomas. The Minories, Jesmond, Newcastle-on-Tyne.
1867. ‡Bell, Thomas. Belmont, Dundee.
1875. §Bell, William. 36 Park-road, New Wandsworth, Surrey, S.W.
1842. Bellhouse, Edward Taylor. Eagle Foundry, Manchester.
1854. ‡Bellhouse, William Dawson. 1 Park-street, Leeds.
Bellingham, Sir Alan. Castle Bellingham, Ireland.
1866. *BELPER, The Right Hon. Lord, M.A., D.C.L., F.R.S., F.G.S. 75 Eaton-square, London, S.W.; and Kingston Hall, Derby.

Year of
Election.

1864. *Bendyshe, T. 13 Buckingham-street, Strand, London, W.C.
1870. ‡BENNETT, ALFRED W., M.A., B.Sc., F.L.S. 6 Park Village East, Regent's Park, London, N.W.
1871. ‡Bennett, F. J. 12 Hillmarten-road, Camden-road, London, N.
1870. *Bennett, William. 109 Shaw-street, Liverpool.
1870. *Bennett, William, jun. Oak Hill Park, Old Swan, near Liverpool.
1852. *Bennoch, Francis, F.S.A. 19 Tavistock-square, London, W.C.
1857. ‡Benson, Charles. 11 Fitzwilliam-square West, Dublin.
Benson, Robert, jun. Fairfield, Manchester.
1848. ‡Benson, Starling, F.G.S. Gloucester-place, Swansea.
1870. ‡Benson, W. Alresford, Hants.
1863. ‡Benson, William. Fourstones Court, Newcastle-on-Tyne.
1848. ‡BENTHAM, GEORGE, F.R.S., F.L.S. 25 Wilton-place, Knightsbridge, London, S.W.
1842. Bentley, John. 9 Portland-place, London, W.
1863. §BENTLEY, ROBERT, F.L.S., Professor of Botany in King's College. 91 Alexandra-road, St. John's-wood, London, N.W.
1875. §Beor, Henry R. 3 Harcourt-buildings, Temple, London, E.C.
1868. ‡BERKELEY, Rev. M. J., M.A., F.L.S. Sibbertoft, Market Harborough.
1863. ‡Berkley, C. Marley Hill, Gateshead, Durham.
1848. ‡Berrington, Arthur V. D. Woodlands Castle, near Swansea.
1866. ‡Berry, Rev. Arthur George. Monyash Parsonage, Bakewell, Derbyshire.
1870. ‡Berwick, George, M.D. 36 Fawcett-street, Sunderland.
1862. ‡Besant, William Henry, M.A., F.R.S. St. John's College, Cambridge.
1865. *BESSEMER, HENRY. Denmark-hill, Camberwell, London, S.E.
1858. ‡Best, William. Leydon-terrace, Leeds.
Bethune, Admiral, C.B., F.R.G.S. Balfour, Fifeshire.
1859. ‡Beveridge, Robert, M.B. 36 King-street, Aberdeen.
1874. *Bevington, James B. Merle Wood, Sevenoaks.
1863. ‡Bewick, Thomas John, F.G.S. Haydon Bridge, Northumberland.
*Bickerdike, Rev. John, M.A. St. Mary's Vicarage, Leeds.
1870. ‡Bickerton, A. W., F.C.S. Hartley Institution, Southampton.
1868. ‡BIDDER, GEORGE PARKER, C.E., F.R.G.S. 24 Great George-street, Westminster, S.W.
1863. ‡Bigger, Benjamin. Gateshead, Durham.
1864. ‡Biggs, Robert. 17 Charles-street, Bath.
1855. ‡Billings, Robert William. 4 St. Mary's-road, Canonbury, London, N.
Bilton, Rev. William, M.A., F.G.S. United University Club, Suffolk-street, London, S.W.; and Chislehurst, Kent.
1842. BINNEY, EDWARD WILLIAM, F.R.S., F.G.S. 40 Cross-street, Manchester.
1873. ‡Binns, J. Arthur. Manningham, Bradford, Yorkshire.
Birchall, Edwin. Airedale Cliff, Newley, Leeds.
Birchall, Henry. College House, Bradford.
1866. *Birkin, Richard. Aspley Hall, near Nottingham.
*Birks, Rev. Thomas Rawson, M.A., Professor of Moral Philosophy in the University of Cambridge. 7 Brookside, Cambridge.
1841. *BIRT, WILLIAM RADCLIFF, F.R.A.S. Cynthia-villa, Clarendon-road, Walthamstow, London, N.E.
1871. *BISCHOF, GUSTAV. 4 Hart-street, Bloomsbury, London, W.C.
1868. ‡Bishop, John. Thorpe Hamlet, Norwich.
1866. ‡Bishop, Thomas. Bramcote, Nottingham.
1869. ‡Blackall, Thomas. 13 Southernhay, Exeter.
Blackburne, Rev. John, M.A. Yarmouth, Isle of Wight.
Blackburne, Rev. John, jun., M.A. Rectory, Horton, near Chippenham.

Year of Election.

1859. ‡Blackie, John Stewart, M.A., Professor of Greek in the University of Edinburgh.
1855. *BLACKIE, W. G., Ph.D., F.R.G.S. 17 Stanhope-street, Glasgow.
1870. ‡Blackmore, W. Founder's-court, Lothbury, London, E.C.
*BLACKWALL, Rev. JOHN, F.L.S. Hendre House, near Llanrwst, Denbighshire.
1863. ‡Blake, C. Carter, Ph.D., F.G.S. St. Michael's-buildings, 9 Gracechurch-street, London, E.C.
1849. *BLAKE, HENRY WOLLASTON, M.A., F.R.S. 8 Devonshire-place, Portland-place, London, W.
1846. *Blake, William. Bridge House, South Petherton, Somerset.
1845. ‡Blakesley, Rev. J. W., B.D. Ware Vicarage, Hertfordshire.
1861. §Blakiston, Matthew. 18 Wilton-crescent, S.W.
*Blakiston, Peyton, M.D., F.R.S. 140 Harley-street, London, W.
1868. ‡BLANC, HENRY, M.D. 9 Bedford-street, Bedford-square, London, W.C.
1869. ‡Blanford, W. T., F.R.S., F.G.S., F.R.G.S., Geological Survey of India, Calcutta. (12 Keppel-street, Russell-square, London, W.C.)
*BLOMEFIELD, Rev. LEONARD, M.A., F.L.S., F.G.S. 19 Belmont, Bath.
Blore, Edward, LL.D., F.R.S., F.S.A. 4 Manchester-square, London, W.
1870. ‡Blundell, Thomas Weld. Ince Blundell Hall, Great Crosby, Lancashire.
1859. ‡Blunt, Sir Charles, Bart. Heathfield Park, Sussex.
1859. ‡Blunt, Capt. Richard. Bretlands, Chertsey, Surrey.
Blyth, B. Hall. 135 George-street, Edinburgh.
1858. *Blythe, William. Holland Bank, Church, near Accrington.
1870. ‡Boardman, Edward. Queen-street, Norwich.
1845. ‡*Bodmer, Rodolphe.*
1866. §Bogg, Thomas Wemyss. Louth, Lincolnshire.
1859. *BOHN, HENRY G., F.L.S., F.R.A.S., F.R.G.S., F.S.S. North End House, Twickenham, S.W.
1871. §Bohn, Mrs. North End House, Twickenham, S.W.
1859. ‡Bolster, Rev. Prebendary John A. Cork.
Bolton, R. L. Laurel Mount, Aigburth-road, Liverpool.
1866. ‡Bond, Banks. Low Pavement, Nottingham.
1863. ‡*Bond, Francis T., M.D.*
Bond, Henry John Hayes, M.D. Cambridge.
1871. §Bonney, Rev. Thomas George, M.A., F.S.A., F.G.S. St. John's College, Cambridge.
Bonomi, Ignatius. 36 Blandford-square, London, N.W.
BONOMI, JOSEPH. Soane's Museum, 15 Lincoln's-Inn-fields, London, W.C.
1866. ‡Booker, W. H. Cromwell-terrace, Nottingham.
1861. §Booth, James. Elmfield, Rochdale.
1835. ‡Booth, Rev. James, LL.D., F.R.S., F.R.A.S., F.R.G.S. The Vicarage, Stone, near Aylesbury.
1861. *Booth, William. Hollybank, Cornbrook, Manchester.
1861. *Borchardt, Louis, M.D. Barton Arcade, Manchester.
1849. ‡Boreham, William W., F.R.A.S. The Mount, Haverhill, Newmarket.
1863. ‡Borries, Theodore. Lovaine-crescent, Newcastle-on-Tyne.
*Bossey, Francis, M.D. Mayfield, Oxford-road, Redhill, Surrey.
BOSWORTH, Rev. JOSEPH, D.D., LL.D., F.R.S., F.S.A., M.R.I.A., Professor of Anglo-Saxon in the University of Oxford. Oxford.
1867. §Botly, William, F.S.A. Salisbury House, Hamlet-road, Upper Norwood, London, S.E.
1858. ‡Botterill, John. Burley, near Leeds.

Year of Election.

1872. ‡Bottle, Alexander. Dover.
1868. ‡Bottle, J. T. 28 Nelson-road, Great Yarmouth.
1871. ‡BOTTOMLEY, JAMES THOMSON, M.A., F.C.S. The College, Glasgow.
Bottomley, William. Forbreda, Belfast.
1850. ‡Bouch, Thomas, C.E. Oxford-terrace, Edinburgh.
1870. ‡Boult, Swinton. 1 Dale-street, Liverpool.
1868. ‡Boulton, W. S. Norwich.
1866. §Bourne, Stephen, F.S S. Abberley Lodge, Hudstone-drive, Harrow.
1872. ‡Bovill, William Edward. 29 James-street, Buckingham-gate, London, S.W.
1870. ‡Bower, Anthony. Bowerdale, Seaforth, Liverpool.
1867. ‡Bower, Dr. John. Perth.
1846. *BOWERBANK, JAMES SCOTT, LL.D., F.R.S., F.G.S., F.L.S., F.R.A.S. 2 East-ascent, St. Leonard's-on-Sea.
1856. *Bowlby, Miss F. E. 27 Lansdown-crescent, Cheltenham.
1863. ‡Bowman, R. Benson. Newcastle-on-Tyne.
Bowman, William, F.R.S., F.R.C.S. 5 Clifford-street, London, W.
1869. ‡Bowring, Charles T. Elmsleigh, Princes Park, Liverpool.
1869. ‡*Bowring, J. C. Larkbeare, Exeter.*
1863. ‡Bowron, James. South Stockton-on-Tees.
1863. §Boyd, Edward Fenwick. Moor House, near Durham.
1871. ‡Boyd, Thomas J. 41 Moray-place, Edinburgh.
1865. ‡BOYLE, Rev. G. D. Soho House, Handsworth, Birmingham.
1872. §BRABROOK, E. W., F.S.A., Dir. A.I. 28 Abingdon-street, Westminster, S.W.
1869. *Braby, Frederick, F.G.S., F.C.S. Mount Henley, Sydenham Hill, London, S.E.
1870. §Brace, Edmund. 9 Exchange-square, Glasgow.
Bracebridge, Charles Holt, F.R.G.S. The Hall, Atherstone, Warwickshire.
1861. *Bradshaw, William. Slade House, Green-walk, Bowdon, Cheshire.
1842. *BRADY, Sir ANTONIO, J.P., F.G.S. Maryland Point, Stratford, Essex, E.
1857. *Brady, Cheyne, M.R.I.A. Four Courts, Co. Dublin.
Brady, Daniel F., M.D. 5 Gardiner's-row, Dublin.
1863. ‡BRADY, GEORGE S. 22 Fawcett-street, Sunderland.
1862. §BRADY, HENRY BOWMAN, F.R.S., F.L.S., F.G.S. 40 Mosley-street, Newcastle-on-Tyne.
1858. ‡*Brae, Andrew Edmund.*
1875. §Bragge, William, F.S.A., F.G.S. Shirle Hill, Sheffield.
1864. §Braham, Philip, F.C.S. 6 George-street, Bath.
1870. §Braidwood, Dr. Delemere-terrace, Birkenhead.
1864. §Braikenridge, Rev. George Weare, M.A., F.L.S. Clevedon, Somerset.
1865. §BRAMWELL, FREDERICK J., M.I.C.E., F.R.S. 37 Great George-street, London, S.W.
1872. §Bramwell, William J. 17 Prince Albert-street, Brighton.
Brancker, Rev. Thomas, M.A. Limington, Somerset.
1867. ‡Brand, William. Milnefield, Dundee.
1861. *Brandreth, Rev. Henry. Dickleburgh Rectory, Scole, Norfolk.
1852. ‡BRAZIER, JAMES S., F.C.S., Professor of Chemistry in Marischal College and University of Aberdeen.
1857. ‡Brazill, Thomas. 12 Holles-street, Dublin.
1869. *BREADALBANE, The Right Hon. the Earl of. Taymouth Castle, N.B.; and Carlton Club, Pall Mall, London, S.W.
1873. §Breffit, Edgar. Castleford, near Normanton.
1868. ‡Bremridge, Elias. 17 Bloomsbury-square, London, W.C.
1869. ‡Brent, Colonel Robert. Woodbury, Exeter.

Year of
Election.

1860. ‡Brett, G. Salford.
1866. ‡Brettell, Thomas (Mine Agent). Dudley.
1865. §Brewin, William. Cirencester.
1875. §Briant, T. Hampton Wick, Kingston-on-Thames.
1867. ‡BRIDGMAN, WILLIAM KENCELEY. 69 St. Giles's-street, Norwich.
1870. *Bridson, Joseph R. Belle Isle, Windermere.
1870. ‡Brierley, Joseph, C.E. New Market-street, Blackburn.
1870. *BRIGG, JOHN. Broomfield, Keighley, Yorkshire.
1866. *Briggs, Arthur. Cragg Royd, Rawdon, near Leeds.
1866. §Briggs, Joseph. Barrow-in-Furness.
1863. *BRIGHT, Sir CHARLES TILSTON, C.E., F.G.S., F.R.G.S., F.R.A.S. 69 Lancaster-gate, W.; and 11 Delahay-street, London, S.W.
1870. ‡Bright, H. A., M.A., F.R.G.S. Ashfield, Knotty Ash.
BRIGHT, The Right Hon. JOHN, M.P. Rochdale, Lancashire.
1868. ‡BRINE, Commander LINDESAY. Army and Navy Club, Pall Mall, London, S.W.
1842. Broadbent, Thomas. Marsden-square, Manchester.
1859. *BRODHURST, BERNARD EDWARD. 20 Grosvenor-street, Grosvenor-square, London, W.
1847. ‡BRODIE, Sir BENJAMIN C., Bart., M.A., D.C.L., F.R.S. Brockham Warren, Reigate.
1834. ‡BRODIE, Rev. JAMES, F.G.S. Monimail, Fifeshire.
1865. ‡BRODIE, Rev. PETER BELLENGER, M.A., F.G.S. Rowington Vicarage, near Warwick.
1853. ‡Bromby, J. H., M.A. The Charter House, Hull.
*BROOKE, CHARLES, M.A., F.R.S., F.R.C.S. 16 Fitzroy-square, London, W.
1855. ‡Brooke, Edward. Marsden House, Stockport, Cheshire.
1864. *Brooke, Rev. J. Ingham. Thornhill Rectory, Dewsbury.
1855. ‡Brooke, Peter William. Marsden House, Stockport, Cheshire.
1863. §Brooks, John Crosse. Wallsend, Newcastle-on-Tyne.
1846. *Brooks, Thomas. Cranshaw Hall, Rawstenstall, Manchester.
Brooks, William. Ordfall Hill, East Retford, Nottinghamshire.
1874. §Broom, William. 20 Woodlands-terrace, Glasgow.
1847. ‡Broome, C. Edward, F.L.S. Elmhurst, Batheaston, near Bath.
1863. *Brough, Lionel H., F.G.S., one of Her Majesty's Inspectors of Coal-Mines. 11 West Mall, Clifton, Bristol.
*BROUN, JOHN ALLAN, F.R.S., late Astronomer to His Highness the Rajah of Travancore. 4 Abercorn-place, St. John's Wood, London, N.W.
1864. ‡Brown, Mrs. 1 Stratton-street, Piccadilly, London, W.
1863. *BROWN, ALEXANDER CRUM, M.D., F.R.S.E., F.C.S., Professor of Chemistry in the University of Edinbugh. 8 Belgrave-crescent, Edinburgh.
1867. ‡Brown, Charles Gage, M.D. 88 Sloane-street, London, S.W.
1855. ‡Brown, Colin. 3 Mansfield-place, Glasgow.
1871. §Brown, David. 93 Abbey-hill, Edinburgh.
1863. *Brown, Rev. Dixon. Unthank Hall, Haltwhistle, Carlisle.
1865. §Brown, Edwin, F.G.S. Burton-upon-Trent.
1858. §Brown, Henry, J.P., LL.D. Daisy Hill, Rawdon, Leeds.
1870. §BROWN, HORACE T. The Bank, Burton-on-Trent.
Brown, Hugh. Broadstone, Ayrshire.
1870. §BROWN, J. CAMPBELL, D.Sc., F.C.S. Royal Infirmary School of Medicine, Liverpool.
1859. ‡Brown, Rev. John Crombie, LL.D., F.L.S. Berwick-on-Tweed.
1863. ‡*Brown, John H.*
1874. ‡Brown, John S. Edenderry, Shaw's Bridge, Belfast.

Year of
Election.

1863. ‡Brown, Ralph. Lambton's Bank, Newcastle-on-Tyne.
1871. ‡BROWN, ROBERT, M.A., Ph.D., F.R.G.S. 4 Gladstone-terrace, Edinburgh.
1868. ‡Brown, Samuel. Grafton House, Swindon, Wilts.
*Brown, Thomas. Gwentland, Chepstow.
*Brown, William. 11 Maiden-terrace, Dartmouth Park, London, N.
1855. ‡Brown, William. 33 Berkeley-terrace, Glasgow.
1850. ‡Brown, William, F.R.S.E. 25 Dublin-street, Edinburgh.
1865. ‡Brown, William. 41A New-street, Birmingham.
1866. *Browne, Rev. J. H. Lowdham Vicarage, Nottingham.
1862. *Browne, Robert Clayton, jun., B.A. Browne's Hill, Carlow, Ireland.
1872. ‡Browne, R. Mackley, F.G.S. Northside, St. John's, Sevenoaks, Kent.
1875. §Browne, Walter R. Bridgwater.
1865. *Browne, William, M.D. The Friary, Lichfield.
1865. §Browning, John, F.R.A.S. 111 Minories, London, E.
1855. §Brownlee, James, jun. 30 Burnbank-gardens, Glasgow.
1853. ‡Brownlow, William B. Villa-place, Hull.
1863. *Brunel, H. M. 23 Delahay-street, Westminster, S.W.
1863. ‡Brunel, J. 23 Delahay-street, Westminster, S.W.
1875. *Brunlees, James, C.E., F.G.S. 5 Victoria-street, Westminster, S.W.
1871. ‡*Brunnow, F.*
1868. ‡BRUNTON, T. LAUDER, M.D., F.R.S. 23 Somerset-street, Portman-square, London, W.
1875. §Bryant, G. Squier. 15 White Ladies'-road, Clifton, Bristol.
1875. §Bryant, Miss S. A. The Castle, Denbigh.
1861. ‡Bryce, James. York Place, Higher Broughton, Manchester.
BRYCE, JAMES, M.A., LL.D., F.R.S.E., F.G.S. 18 Mornington-place, Edinburgh.
BRYCE, Rev. R. J., LL.D., Principal of Belfast Academy. Belfast.
1859. ‡Bryson, William Gillespie. Cullen, Aberdeen.
1867. ‡BUCCLEUCH and QUEENSBERRY, His Grace the Duke of, K.G., D.C.L., F.R.S. L. & E., F.L.S. Whitehall-gardens, London, S.W.; and Dalkeith House, Edinburgh.
1871. §BUCHAN, ALEXANDER, M.A., F.R.S.E., Sec. Scottish Meterological Society. 72 Northumberland-street, Edinburgh.
1867. ‡Buchan, Thomas. Strawberry Bank, Dundee.
BUCHANAN, ANDREW, M.D. Professor of the Institutes of Medicine in the University of Glasgow. 4 Ethol-place, Glasgow.
Buchanan, Archibald. Catrine, Ayrshire.
Buchanan, D. C. Poulton cum Seacombe, Cheshire.
1871. ‡Buchanan, John Y. 10 Moray-place, Edinburgh.
1864. §BUCKLE, Rev. GEORGE, M.A. Twerton Vicarage, Bath.
1865. *Buckley, Henry. 27 Wheeley's-road, Edgbaston, Birmingham.
1848. *BUCKMAN, Professor JAMES, F.L.S., F.G.S. Bradford Abbas, Sherborne, Dorsetshire.
1869. ‡Bucknill, J., M.D., F.R.S. Hillmorton Hall, near Rugby.
1851. *BUCKTON, GEORGE BOWDLER, F.R.S., F.L.S., F.C.S. Weycombe, Haslemere, Surrey.
1848. *BUDD, JAMES PALMER. Ystalyfera Iron Works, Swansea.
1875. §Budgett, Samuel. Cotham House, Bristol.
1871. §Bulloch, Matthew. 11 Park-circus, Glasgow.
1845. *BUNBURY, Sir CHARLES JAMES FOX, Bart., F.R.S., F.L.S., F.G.S., F.R.G.S. Barton Hall, Bury St. Edmunds.
1865. ‡Bunce, John Mackray. 'Journal Office,' New-street, Birmingham.
1863. §Bunning, T. Wood. Institute of Mining and Mechanical Engineers, Newcastle-on-Tyne.

Year of Election.
1842. *Burd, John. 5 Gower-street, London, W.C.
1875. §Burder, John, M.D. 7 South Parade, Bristol.
1869. ‡Burdett-Coutts, Baroness. Stratton-street, Piccadilly, London, W.
1874. ‡Burdon, Henry, M.D. Clandeboye, Belfast.
1872. *Burgess, Herbert. 62 High-street, Battle, Sussex.
1857. ‡*Burk, J. Lardner, LL.D.*
1865. ‡*Burke, Luke. 5 Albert Terrace, Acton, London, W.*
1869. **Burnell, Arthur Coke.*
1859. ‡Burnett, Newell. Belmont-street, Aberdeen.
1860. ‡Burrows, Montague, M.A., Professor of Modern History, Oxford.
1874. §Burt, Rev. J. T. Broadmoor, Berks.
1866. *BURTON, FREDERICK M., F.G.S. Highfield, Gainsborough.
1864. ‡Bush, W. 7 Circus, Bath.
Bushell, Christopher. Royal Assurance-buildings, Liverpool.
1855. *BUSK, GEORGE, F.R.S., V.P.L.S., F.G.S., Examiner in Comparative Anatomy in the University of London. 32 Harley-street, Cavendish-square, London, W.
1857. ‡Butt, Isaac, Q.C., M.P. 64 Eccles-street, Dublin.
1855. *Buttery, Alexander W. Cardarroch House, near Airdrie.
1872. ‡Buxton, Charles Louis. Cromer, Norfolk.
1870. ‡Buxton, David, Principal of the Liverpool Deaf and Dumb Institution, Oxford-street, Liverpool.
1868. ‡Buxton, S. Gurney. Catton Hall, Norwich.
1872. ‡Buxton, Sir T. Fowell. Warlies, Waltham Abbey, Essex.
1854. ‡BYERLEY, ISAAC, F.L.S. Seacombe, Liverpool.
Byng, William Bateman. 2 Bank-street, Ipswich.
1852. ‡Byrne, Very Rev. James. Ergenagh Rectory, Omagh.
1875. §Byrom, W. Ascroft, F.G.S. 27 King-street, Wigan.

1858. §Cail, John. Stokesley, Yorkshire.
1863. ‡Cail, Richard. Beaconsfield, Gateshead.
1854. ‡Caine, Nathaniel. 38 Belvedere-road, Princes Park, Liverpool.
1858. *Caine, Rev. William, M.A. Christ Church Rectory, Denton, near Manchester.
1863. ‡Caird, Edward. Finnart, Dumbartonshire.
1861. *Caird, James Key. 8 Magdalene-road, Dundee.
1855. *Caird, James Tennant. Shipyard, Greenock.
1875. §Caldicott, Rev. J. W., D.D. The Grammar School, Bristol.
1868. ‡Caley, A. J. Norwich.
1868. ‡Caley, W. Norwich.
1857. ‡Callan, Rev. N. J., Professor of Natural Philosophy in Maynooth College.
1853. ‡Calver, Captain E. K., R.N., F.R.S. The Grange, Redhill, Surrey.
1857. ‡Cameron, Charles A., M.D. 15 Pembroke-road, Dublin.
1870. ‡Cameron, John, M.D. 17 Rodney-street, Liverpool.
1859. ‡Campbell, Rev. C. P., Principal of King's College, Aberdeen.
1857. *Campbell, Dugald, F.C.S. 7 Quality-court, Chancery-lane, London, W.C.
1874. *CAMPBELL, Sir GEORGE, K.C.S.I., M.P., D.C.L., F.R.G.S. 13 Cornwall-gardens, South Kensington, London, S.W.; and Edenwood, Cupar, Fife.
Campbell, Sir Hugh P. H., Bart. 10 Hill-street, Berkeley-square, London, W.; and Marchmont House, near Dunse, Berwickshire.
*Campbell, Sir James. 129 Bath-street, Glasgow.
Campbell, John Archibald, M.D., F.R.S.E. Albyn-place, Edinburgh.
1872. ‡CAMPBELL, Rev. J. R., D.D. 5 Eldon-place, Manningham-lane, Bradford, Yorkshire.

Year of Election.

1859. ‡Campbell, William. Dunmore, Argyllshire.
1871. ‡Campbell, William Hunter, LL.D. Georgetown, Demerara, British Guiana. (Messrs. Ridgway & Sons, 2 Waterloo-place, London, S.W.)
CAMPBELL-JOHNSTON, ALEXANDER ROBERT, F.R.S. 84 St. George's-square, London, S.W.
1862. *CAMPION, Rev. Dr. WILLIAM M. Queen's College, Cambridge.
1868. *Cann, William. 9 Southernhay, Exeter.
1873. *Carbutt, Edward Hamer, C.E. St. Ann's, Burley, Leeds, Yorkshire.
*Carew, William Henry Pole. Antony, Torpoint, Devonport.
CARLISLE, The Right Rev. HARVEY GOODWIN, D.D., Lord Bishop of Carlisle.
1861. ‡Carlton, James. Mosley-street, Manchester.
1867. ‡Carmichael, David (Engineer). Dundee.
1867. ‡Carmichael, George. 11 Dudhope-terrace, Dundee.
Carmichael, H.
Carmichael, John T. C. Messrs. Todd & Co., Cork.
1871. ‡CARPENTER, CHARLES. Brunswick-square, Brighton.
1871. §Carpenter, Herbert P. 56 Regent's Park-road, London, N.W.
*CARPENTER, PHILIP PEARSALL, B.A., Ph.D. Montreal, Canada. (Care of Dr. W. B. Carpenter, 56 Regent's Park-road, London, N.W.)
1854. ‡Carpenter, Rev. R. Lant, B.A. Bridport.
1845. ‡CARPENTER, WILLIAM B., C.B., M.D., LL.D., F.R.S., F.L.S., F.G.S., Registrar of the University of London. 56 Regent's Park-road, London, N.W.
1872. §CARPENTER, WILLIAM LANT, B.A., B.Sc., F.C.S. Winifred House, Pembroke-road, Clifton, Bristol.
1842. *Carr, William, M.D, F.L.S., F.R.C.S. Lee Grove, Blackheath, S.E.
1867. §CARRUTHERS, WILLIAM, F.R.S., F.L.S., F.G.S. British Museum, London, W.C.
1861. *Carson, Rev. Joseph, D.D., M.R.I.A. 18 Fitzwilliam-place, Dublin.
1857. ‡CARTE, ALEXANDER, M.D. Royal Dublin Society, Dublin.
1868. §Carteighe, Michael, F.C.S. 172 New Bond-street, London, W.
1866. ‡Carter, H. H. The Park, Nottingham.
1855. ‡Carter, Richard, C.E., F.G.S. Cockerham Hall, Barnsley, Yorkshire.
1870. ‡Carter, Dr. William. 69 Elizabeth-street, Liverpool.
*CARTMELL, Rev. JAMES, D.D., F.G.S., Master of Christ's College. Christ College Lodge, Cambridge.
Cartmell, Joseph, M.D. Carlisle.
1870. §Cartwright, Joshua. 70 King-street. Dukinfield.
1862. ‡Carulla, Facundo, F.A.S.L. Care of Messrs. Daglish and Co., 8 Harrington-street, Liverpool.
1868. ‡Cary, Joseph Henry. Newmarket-road, Norwich.
1866. ‡Casella, L. P., F.R.A.S. South-grove, Highgate, London, N.
1871. §Cash, Joseph. Bird Grove, Coventry.
1873. *Cash, William, Elmfield-terrace, Saville Park, Halifax.
1842. **Cassels, Rev. Andrew, M.A.*
Castle, Charles. Clifton, Bristol.
1874. §Caton, Richard, M.D., Lecturer on Physiology at the Liverpool Medical School. 18A Abercromby-square, Liverpool.
1853. ‡Cator, John B., Commander R.N. 1 Adelaide-street, Hull.
1859. ‡Catto, Robert. 44 King-street, Aberdeen.
1866. ‡*Catton, Alfred, R., M.A., F.R.S.E.*
1873. *Cavendish, Lord Frederick, M.P. 21 Carlton House-terrace, London, S.W.

Year of Election.

1849. ‡Cawley, Charles Edward. The Heath, Kirsall, Manchester.
1860. §CAYLEY, ARTHUR, LL.D., F.R.S., V.P.R.A.S., Sadlerian Professor of Mathematics in the University of Cambridge. Garden House, Cambridge.
Cayley, Digby. Brompton, near Scarborough.
Cayley, Edward Stillingfleet. Wydale, Malton, Yorkshire.
1871. *Cecil, Lord Sackville. Hayes Common, Beckenham, Kent.
1870. ‡Chadburn, C. H. Lord-street, Liverpool.
1858. *Chadwick, Charles, M.D. Lynncourt, Broadwater Down, Tunbridge Wells.
1860. ‡CHADWICK, DAVID, M.P. 27 Belsize-park, London, N.W.
1842. CHADWICK, EDWIN, C.B. Richmond, Surrey.
1842. Chadwick, Elias, M.A. Pudleston Court, near Leominster.
1859. ‡Chadwick, Robert. Highbank, Manchester.
1861. ‡Chadwick, Thomas. Wilmslow Grange, Cheshire.
*CHALLIS, Rev. JAMES, M.A., F.R.S., F.R.A.S., Plumian Professor of Astronomy in the University of Cambridge. 2 Trumpington-street, Cambridge.
1859. ‡Chalmers, John Inglis. Aldbar, Aberdeen.
1865. ‡CHAMBERLAIN, J. H. Christ Church-buildings, Birmingham.
1868. ‡Chamberlin, Robert. Catton, Norwich.
1842. Chambers, George. High Green, Sheffield.
Chambers, John.
1868. ‡Chambers, W. O. Lowestoft, Suffolk.
*Champney, Henry Nelson. 4 New-street, York.
1865. ‡Chance, A. M. Edgbaston, Birmingham.
1865. *Chance, James T. Four Oaks Park, Sutton Coldfield, Birmingham.
1865. §Chance, Robert Lucas. Chad Hill, Edgbaston, Birmingham.
1861. *Chapman, Edward, M.A., F.L.S., F.C.S. Frewen Hall, Oxford.
1861. *Chapman, John, M.P. Hill End, Mottram, Manchester.
1866. ‡Chapman, William. The Park, Nottingham.
1871. §Chappell, William, F.S.A. Strafford Lodge, Oatlands Park, Weybridge Station.
1874. §Charles, John James, M.A., M.D. 11 Fisherwick-place, Belfast.
1871. ‡Charles, T. C., M.D. Queen's College, Belfast.
1836. CHARLESWORTH, EDWARD, F.G.S. 113A Strand, London, W.C.
1874. ‡Charley, William. Seymour Hill, Dunmurry, Ireland.
1863. ‡Charlton, Edward, M.D. 7 Eldon-square, Newcastle-on-Tyne.
1866. ‡CHARNOCK, RICHARD STEPHEN, Ph.D., F.S.A., F.R.G.S. 8 Gray's-Inn-square, London, W.C.
Chatto, W. J. P. Union Club, Trafalgar-square, London, S.W.
1867. *Chatwood, Samuel. 5 Wentworth-place, Bolton.
1864. ‡CHEADLE, W. B., M.A., M.D., F.R.G.S. 2 Hyde Park-place, Cumberland-gate, London, W.
1874. *Chermside, Lieutenant H. C., R.E. Care of Messrs. Cox & Co., Craig's-court, Charing Cross, London, S.W.
1872. §CHICHESTER, The Right Hon. the Earl of. Stanmer House, Lewes.
CHICHESTER, The Right Rev. RICHARD DURNFORD, Lord Bishop of. Chichester.
1865. *Child, Gilbert W., M.A., M.D., F.L.S. Oxford.
1842. *Chiswell, Thomas. 17 Lincoln-grove, Plymouth-grove, Manchester.
1863. ‡Cholmeley, Rev. C. H. Dinton Rectory, Salisbury.
1859. ‡Christie, John, M.D. 46 School-hill, Aberdeen.
1861. ‡Christie, Professor R. C., M.A. 7 St. James's-square, Manchester.
CHRISTISON, Sir ROBERT, Bart., M.D., D.C.L., F.R.S.E., Professor of Dietetics, Materia Medica, and Pharmacy in the University of Edinburgh. Edinburgh.

Year of Election.

1875. *Christopher, George, F.C.S. (ASSISTANT GENERAL TREASURER.) University College, London, W.C.
1870. §CHURCH, A. H., F.C.S., Professor of Chemistry in the Royal Agricultural College, Cirencester.
1860. ‡Church, William Selby, M.A. St. Bartholomew's Hospital, London, E.C.
1857. ‡Churchill, F., M.D. 15 Stephen's-green, Dublin.
1868. ‡Clabburn, W. H. Thorpe, Norwich.
1863. ‡Clapham, A. 3 Oxford-street, Newcastle-on-Tyne.
1863. ‡Clapham, Henry. 5 Summerhill-grove, Newcastle-on-Tyne.
1855. §CLAPHAM, ROBERT CALVERT. Garsdon House, Garsdon, Newcastle-on-Tyne.
1869. §Clapp, Frederick. 44 Magdalen-street, Exeter.
1857. ‡Clarendon, Frederick Villiers. 1 Belvidere-place, Mountjoy-square, Dublin.
Clark, Courtney K.
1859. ‡Clark, David. Coupar Angus, Fifeshire.
Clark, G. T. Bombay; and Athenæum Club, London, S.W.
1846. **Clark, Henry, M.D. 2 Arundel-gardens, Kensington, London, W.*
1861. ‡Clark, Latimer. 5 Westminster-chambers, Victoria-street, London, S.W.
1855. ‡Clark, Rev. William, M.A. Barrhead, near Glasgow.
1865. ‡Clarke, Rev. Charles. Charlotte-road, Edgbaston, Birmingham.
1875. §Clarke, Charles S. 4 Worcester-terrace, Clifton, Bristol.
Clarke, George. Mosley-street, Manchester.
1872. *CLARKE, HYDE. 32 St. George's-square, Pimlico, London, S.W.
1861. *Clarke, J. H. Lark Hill House, Edgeley, Stockport.
1875. §CLARKE, JOHN HENRY. 4 Worcester-terrace, Clifton, Bristol.
1842. *Clarke, Joseph.*
1851. ‡CLARKE, JOSHUA, F.L.S. Fairycroft, Saffron Walden.
Clarke, Thomas, M.A. Knedlington Manor, Howden, Yorkshire.
1861. ‡Clay, Charles, M.D. 101 Piccadilly, Manchester.
*Clay, Joseph Travis, F.G.S. Rastrick, near Brighouse, Yorkshire.
1856. *Clay, Colonel William. The Slopes, Wallasea, Cheshire.
1866. ‡Clayden, P. W. 13 Tavistock-square, London, W.C.
1875. §Clegram, T. W. B. Saul Lodge, near Stonehouse, Gloucestershire.
1850. ‡CLEGHORN, HUGH, M.D., F.L.S., late Conservator of Forests, Madras. Stravithy, St. Andrews, Scotland.
1859. ‡Cleghorn, John. Wick.
1861. §CLELAND, JOHN, M.D., F.R.S., Professor of Anatomy and Physiology in Queen's College, Galway. Vicarscroft, Galway.
1857. ‡Clements, Henry. Dromin, Listowel, Ireland.
‡Clerk, Rev. D. M. Deverill, Warminster, Wiltshire.
1852. ‡Clibborn, Edward. Royal Irish Academy, Dublin.
1873. §Cliff, John. Halton, Runcorn.
1869. §CLIFFORD, WILLIAM KINGDON, M.A., F.R.S., Professor of Applied Mathematics and Mechanics in University College, London. 26 Colville-road, Bayswater, London, W.
1865. ‡Clift, John E., C.E. Redditch, Bromsgrove, near Birmingham.
1861. *CLIFTON, R. BELLAMY, M.A., F.R.S., F.R.A.S., Professor of Experimental Philosophy in the University of Oxford. Portland Lodge, Park Town, Oxford.
Clonbrock, Lord Robert. Clonbrock, Galway.
1854. ‡Close, The Very Rev. Francis, M.A. Carlisle.
1866. §CLOSE, THOMAS, F.S.A. St. James's-street, Nottingham.
1873. ‡Clough, John. Bracken Bank, Keighley, Yorkshire.
1859. ‡Clouston, Rev. Charles. Sandwick, Orkney.

Year of
Election.

1861. *Clouston, Peter. 1 Park-terrace, Glasgow.
1863. *Clutterbuck, Thomas. Warkworth, Acklington.
1868. ‡Coaks, J. B. Thorpe, Norwich.
1855. *Coats, Sir Peter. Woodside, Paisley.
1855. *Coats, Thomas. Ferguslie House, Paisley.
Cobb, Edward. 20 Park-street, Bath.
1851. *COBBOLD, JOHN CHEVALLIER. Holywells, Ipswich; and Athenæum Club, London, S.W.
1864. ‡COBBOLD, T. SPENCER, M.D., F.R.S., F.L.S., Lecturer on Zoology and Comparative Anatomy at the Middlesex Hospital. 42 Harley-street, London, W.
1864. *Cochrane, James Henry. 129 Lower Baggot-street, Dublin.
1854. ‡*Cockey, William.*
1861. *Coe, Rev. Charles C., F.R.G.S. Highfield, Manchester-road, Bolton.
1865. ‡Coghill, H. Newcastle-under-Lyme.
1853. ‡Colchester, William, F.G.S. Grundesburgh Hall, Ipswich.
1868. ‡Colchester, W. P. Bassingbourn, Royston.
1859. *Cole, Henry Warwick, Q.C. 23 High-street, Warwick.
1860. ‡Coleman, J. J., F.C.S. 69 St. George's-place, Glasgow.
1854. *Colfox, William, B.A. Westmead, Bridport, Dorsetshire.
1857. ‡Colles, William, M.D. 21 Stephen's-green, Dublin.
1861. **Collie, Alexander.* 12 *Kensington Palace-gardens, London, W.*
1869. ‡Collier, W. F. Woodtown, Horrabridge, South Devon.
1854. ‡COLLINGWOOD, CUTHBERT, M.A., M.B., F.L.S. 4 Grove-terrace, Belvedere-road, Upper Norwood, Surrey, S.E.
1861. *Collingwood, J. Frederick, F.G.S. Anthropological Institute, 4 St. Martin's-place, London, W.C.
1865. *Collins. James Tertius. 12 Church-road, Edgbaston, Birmingham.
Collis, Stephen Edward. Listowel, Ireland.
1868. *COLMAN, J. J., M.P. Carrow House, Norwich; and 108 Cannon-street, London, E.C.
1870. §Coltart, Robert. The Hollies, Aigburth-road, Liverpool.
Colthurst, John. Clifton, Bristol.
1874. ‡Combe, James. Ormiston House, Belfast.
*COMPTON, The Ven. Lord ALWYN. Castle Ashby, Northamptonshire; and 145 Piccadilly, London, W.
1846. *Compton, Lord William. 145 Piccadilly, London, W.
1852. ‡Connal, Michael. 16 Lynedock-terrace, Glasgow.
1871. *Connor, Charles C. Hope House, College Park East, Belfast.
1864. *Conwell, Eugene Alfred, M.R.I.A. The Model Schools, Cork.
1863. ‡COOKE, EDWARD WILLIAM, R.A., F.R.S., F.R.G.S., F.L.S., F.G.S. Glen Andred, Groombridge, Sussex; and Athenæum Club, Pall Mall, London, S.W.
1868. ‡Cooke, Rev. George H. Wanstead Vicarage, near Norwich.
1875. §Cooke, Henry. The Paragon, Clifton, Bristol.
Cooke, James R., M.A. 73 Blessington-street, Dublin.
Cooke, J. B. Cavendish-road, Birkenhead.
1868. ‡COOKE, M. C., M.A. 2 Grosvenor-villas, Upper Holloway, London, N.
Cooke, Rev. T. L., M.A. Magdalen College, Oxford.
Cooke, Sir William Fothergill. Telegraph Office, Lothbury, London, E.C.
1859. *Cooke, William Henry, M.A., Q.C., F.S.A. 42 Wimpole-street, London, W.; and Rainthorpe Hall, Long Stratton.
1865. ‡Cooksey, Joseph. West Bromwich, Birmingham.
1862. *Cookson, Rev. H. W., D.D. St. Peter's College Lodge, Cambridge.
1863. ‡Cookson, N. C. Benwell Tower, Newcastle-on-Tyne.
1869. §Cooling, Edwin. Mile Ash, Derby.

Year of Election.

1850. ‡COOPER, Sir HENRY, M.D. 7 Charlotte-street, Hull.
Cooper, James. 58 Pembridge-villas, Bayswater, London, W.
1875. §Cooper, T. T. Surbiton, Kent.
1868. ‡Cooper, W. J. The Old Palace, Richmond, Surrey.
1846. ‡Cooper, William White. 19 Berkeley-square, London, W.
1871. ‡Copeland, Ralph, Ph.D. Parsonstown, Ireland.
1868. ‡Copeman, Edward, M.D. Upper King-street, Norwich.
1863. ‡Coppin, John. North Shields.
1842. *Corbet, Richard. Bayshill Lawn, Cheltenham.
1842. Corbett, Edward. Ravenoak, Cheadle-hulme, Cheshire.
1855. ‡Corbett, Joseph Henry, M.D., Professor of Anatomy and Physiology, Queen's College, Cork.
1870. *CORFIELD, W. H., M.A., M.B., F.G.S., Professor of Hygiène and Public Health in University College. 10 Bolton-row, Mayfair, London, W.
Cormack, John Rose, M.D., F.R.S.E.
Cory, Rev. Robert, B.D., F.C.P.S. Stanground, Peterborough.
Cottam, George. 2 Winsley-street, London, W.
1857. ‡Cottam, Samuel. Brazennose-street, Manchester.
1855. ‡Cotterill, Rev. Henry, Bishop of Edinburgh. Edinburgh.
1874. *Cotterill, J. H., M.A., Professor of Applied Mechanics. Royal Naval College, Greenwich, S.E.
1864. §COTTON, General FREDERICK C. Athenæum Club, Pall Mall, London, S.W.
1869. ‡COTTON, WILLIAM. Pennsylvania, Exeter.
*Cotton, Rev. William Charles, M.A. Vicarage, Frodsham, Cheshire.
1874. §Courtald, John. Bocking Bridge, Essex.
1865. ‡Courtald, Samuel, F.R.A.S. 76 Lancaster-gate, London, W.; and Gosfield Hall, Essex.
1834. ‡Cowan, Charles. 38 West Register-street, Edinburgh.
Cowan, John. Valleyfield, Pennycuick, Edinburgh.
1863. ‡Cowan, John A. Blaydon Burn, Durham.
1863. ‡Cowan, Joseph, jun. Blaydon, Durham.
1872. *Cowan, Thomas William. Hawthorn House, Horsham.
1873. *Cowans, John. Cranford, Middlesex.
Cowie, The Very Rev. Benjamin Morgan, M.A., B.D., Dean of Manchester. The Deanery, Manchester.
1871. ‡Cowper, C. E. 3 Great George-street, Westminster, S.W.
1860. ‡Cowper, Edward Alfred, M.I.C.E. 6 Great George-street, Westminster, S.W.
1867. *Cox, Edward. 18 Windsor-street, Dundee.
1867. *Cox, George Addison. Beechwood, Dundee.
1867. ‡Cox, James. Clement Park, Lochee, Dundee.
1870. *Cox, James. 8 Falkner-square, Liverpool.
Cox, Robert. 25 Rutland-street, Edinburgh.
1867. *Cox, Thomas Hunter. Duncarse, Dundee.
1867. ‡Cox, William. Foggley, Lochee, by Dundee.
1866. *Cox, William H. 50 Newhall-street, Birmingham.
1871. ‡Cox, William J. 2 Vanburgh-place, Leith.
Craig, J. T. Gibson, F.R.S.E. 24 York-place, Edinburgh.
1859. ‡Craig, S. The Wallands, Lewes, Sussex.
1857. ‡Crampton, Rev. Josiah., M.R.I.A. The Rectory, Florence-court, Co. Fermanagh, Ireland.
1858. ‡Cranage, Edward, Ph.D. The Old Hall, Wellington, Shropshire.
1871. *Crawford, William Caldwell. Eagle Foundry, Port Dundas, Glasgow.
1871. ‡Crawshaw, Edward. Burnley, Lancashire.
1870. *Crawshay, Mrs. Robert. Cyfarthfa Castle, Merthyr Tydvil.

Year of Election.

Creyke, The Venerable Archdeacon. Bolton Percy Rectory, Tadcaster.
1865. ‡*Crocker, Edwin, F.C.S. 76 Hungerford-road, Holloway, London, N.*
1858. ‡Crofts, John. Hillary-place, Leeds.
1859. ‡Croll, A. A. 10 Coleman-street, London, E.C.
1857. ‡Crolly, Rev. George. Maynooth College, Ireland.
1855. ‡*Crompton, Charles, M.A.*
*CROMPTON, Rev. JOSEPH, M.A. Bracondale, Norwich.
1866. ‡Cronin, William. 4 Brunel-terrace, Nottingham.
1870. ‡Crookes, Joseph. Marlborough House, Brook Green, Hammersmith, London, W.
1865. §CROOKES, WILLIAM, F.R.S., F.C.S. 20 Mornington-road, Regent's Park, London, N.W.
1855. ‡Cropper, Rev. John. Wareham, Dorsetshire.
1870. ‡Crosfield, C. J. 5 Alexandra-drive, Prince's Park, Liverpool.
1870. *Crosfield, William, jun. 5 Alexandra-drive, Prince's Park, Liverpool.
1870. ‡Crosfield, William, sen. Annesley, Aigburth, Liverpool.
1861. ‡Cross, Rev. John Edward, M.A. Appleby Vicarage, near Brigg.
1868. ‡Crosse, Thomas William. St. Giles's-street, Norwich.
1867. §CROSSKEY, Rev. H. W., F.G.S. 28 George-street, Edgbaston, Birmingham.
1853. ‡Crosskill, William, C.E. Beverley, Yorkshire.
1870. *Crossley, Edward, F.R.A.S. Bermerside, Halifax.
1871. ‡Crossley, Herbert. Broomfield, Halifax.
1866. *Crossley, Louis J., F.M.S. Moorside Observatory, near Halifax.
1861. §Crowley, Henry. Smedley New Hall, Cheetham, Manchester.
1863. ‡Cruddas, George. Elswick Engine Works, Newcastle-on-Tyne.
1860. ‡Cruickshank, John. City of Glasgow Bank, Aberdeen.
1859. ‡Cruickshank, Provost. Macduff, Aberdeen.
1873. §Crust, Walter. Hall-street, Spalding.
Culley, Robert. Bank of Ireland, Dublin.
1859. ‡Cumming, Sir A. P. Gordon, Bart. Altyre.
1874. ‡Cumming, Professor. 33 Wellington-place, Belfast.
1861. *Cunliffe, Edward Thomas. The Elms, Handforth, Manchester.
1861. *Cunliffe, Peter Gibson. The Elms, Handforth, Manchester.
1852. ‡Cunningham, John. Macedon, near Belfast.
1869. ‡CUNNINGHAM, Professor ROBERT O., M.D., F.L.S. Queen's College, Belfast.
1855. ‡Cunningham, William A. Manchester and Liverpool District Bank, Manchester.
1850. ‡Cunningham, Rev. William Bruce. Prestonpans, Scotland.
1866. ‡Cunnington, John. 68 Oakley-square, Bedford New Town, London, N.W.
1867. *Cursetjee, Manockjee, F.R.S.A., Judge of Bombay. Villa-Byculla, Bombay.
1857. ‡CURTIS, Professor ARTHUR HILL, LL.D. Queen's College, Galway.
1866. ‡*Cusins, Rev. F. L.*
1834. *Cuthbert, John Richmond. 40 Chapel-street, Liverpool.

1863. ‡Daglish, John. Hetton, Durham.
1854. ‡Daglish, Robert, C.E. Orrell Cottage, near Wigan.
1863. ‡Dale, J. B. South Shields.
1853. ‡Dale, Rev. P. Steele, M.A. Hollingfare, Warrington.
1865. ‡Dale, Rev. R. W. 12 Calthorpe-street, Birmingham.
1867. ‡Dalgleish, W Dundee.
1870. ‡*Dallinger, Rev. W. H.*

Year of Election.

Dalmahoy, James, F.R.S.E. 9 Forres-street, Edinburgh.
1859. ‡Dalrymple, Charles Elphinstone. West Hall, Aberdeenshire.
1859. ‡Dalrymple, Colonel. Troup, Scotland.
Dalton, Edward, LL.D., F.S.A. Dunkirk House, Nailsworth.
*Dalton, Rev. J. E., B.D. Seagrave, Loughborough.
Dalziel, John, M.D. Holm of Drumlanrig, Thornhill, Dumfriesshire.
1862. ‡Danby, T. W. Downing College, Cambridge.
1859. ‡Dancer, J. B., F.R.A.S. Old Manor House, Ardwick, Manchester.
1873. ‡Danchill, F. H. Vale Hall, Horwich, Bolton, Lancashire.
1849. **Danson, Joseph, F.C.S.*
1861. *DARBISHIRE, ROBERT DUKINFIELD, B.A., F.G.S. 26 George-street, Manchester.
DARWIN, CHARLES R., M.A., F.R.S., F.L.S., F.G.S., Hon. F.R.S.E., and M.R.I.A. Down, near Bromley, Kent.
1848. ‡DaSilva, Johnson. Burntwood, Wandsworth Common, London, S.W.
1872. §Davenport, John T. 64 Marine Parade, Brighton.
Davey, Richard, F.G.S. Redruth, Cornwall.
1870. ‡Davidson, Alexander, M.D. 8 Peel-street, Toxteth Park, Liverpool.
1859. ‡Davidson, Charles. Grove House, Auchmull, Aberdeen.
1871. §Davidson, James. Newbattle, Dalkeith, N.B.
1859. ‡Davidson, Patrick. Inchmarlo, near Aberdeen.
1872. ‡DAVIDSON, THOMAS, F.R.S., F.G.S. 3 Leopold-road, Brighton.
1868. ‡*Davie, Rev. W. C.*
1875. §Davies, David. 2 Queen's-square, Bristol.
1870. ‡Davies, Edward, F.C.S. Royal Institution, Liverpool.
1863. ‡Davies, Griffith. 17 Cloudesley-street, Islington, London, N.
Davies, John Birt, M.D. The Laurels, Edgbaston, Birmingham.
1842. Davies-Colley, Dr. Thomas. 40 Whitefriars, Chester.
1873. *Davis, Alfred. Sun Foundry, Leeds.
1870. *Davis, A. S. 37 Montpellier-villas, Cheltenham.
1864. ‡DAVIS, CHARLES E., F.S.A. 55 Pulteney-street, Bath.
Davis, Rev. David, B.A. Lancaster.
1873. *Davis, James W. Albert House, Greetland, near Halifax.
1856. *DAVIS, Sir JOHN FRANCIS, Bart., K.C.B., F.R.S., F.R.G.S. Hollywood, Westbury by Bristol.
1859. ‡DAVIS, J. BARNARD, M.D., F.R.S., F.S.A. Shelton, Hanley, Staffordshire.
1859. *Davis, Richard, F.L.S. 9 St. Helen's-place, London, E.C.
1873. ‡Davis, William Samuel. 1 Cambridge-villas, Derby.
1864. *Davison, Richard. Beverley-road, Great Driffield, Yorkshire.
1857. ‡Davy, Edmund W., M.D. Kimmage Lodge, Roundtown, near Dublin.
1869. ‡Daw, John. Mount Radford, Exeter.
1869. ‡Daw, R. M. Bedford-circus, Exeter.
1854. *Dawbarn, William. Elmswood, Aigburth, Liverpool.
Dawes, John Samuel, F.G.S. Lappel Lodge, Quinton, near Birmingham.
1860. *Dawes, John T., jun. Perry Hill House, Quinton, near Birmingham.
1864. ‡DAWKINS, W. BOYD, M.A., F.R.S., F.G.S., F.S.A. Birchview, Norman-road, Rusholme, Manchester.
1865. ‡Dawson, George, M.A. Shenstone, Lichfield.
Dawson, John. Barley House, Exeter.
1855. ‡DAWSON, JOHN W., M.A., LL.D., F.R.S., Principal of M'Gill College, Montreal, Canada.

Year of Election.

1859. *Dawson, Captain William G. Plumstead Common-road, Kent, S.E.
1871. ‡Day, St. John Vincent. 166 Buchanan-street, Glasgow.
1870. §Deacon, G. F., M.I.C.E. Rock Ferry, Liverpool.
1861. ‡Deacon, Henry. Appleton House, near Warrington.
1870. ‡*Deacon, Henry Wade.*
1859. †Dean, David. Banchory, Aberdeen.
1861. ‡Dean, Henry. Colne, Lancashire.
1870. *Deane, Rev. George, D.Sc., B.A., F.G.S. Moseley, Birmingham.
1866. ‡DEBUS, HEINRICH, Ph.D., F.R.S., F.C.S. Lecturer on Chemistry at Guy's Hospital, London, S.E.
1854. *DE LA RUE, WARREN, D.C.L., Ph.D., F.R.S., F.C.S., F.R.A.S. 73 Portland-place, London, W.
1870. ‡De Meschin, Thomas, M.A., LL.D. 3 Middle Temple-lane, Temple, London, E.C.
Denchar, John. Morningside, Edinburgh.
1875. §Denny, William. Seven Ship-yard, Dumbarton.
Dent, William Yerbury. Royal Arsenal, Woolwich, S.E.
1870. *Denton, J. Bailey. 22 Whitehall-place, London, S.W.
1874. §DE RANCE, CHARLES E., F.G.S. 28 Jermyn-street, London, S.W.
1856. *DERBY, The Right Hon. the Earl of, LL.D., F.R.S., F.R.G.S. 23 St. James's-square, London, S.W.; and Knowsley, near Liverpool.
1874. *Derham, Walter, B.A., F.G.S. Henleaze Park, Westbury-on-Trym, Bristol.
De Saumarez, Rev. Havilland, M.A. St. Peter's Rectory, Northampton.
1870. ‡Desmond, Dr. 44 Irvine-street, Edge Hill, Liverpool.
1868. ‡Dessé, Etheldred, M.B., F.R.C.S. 43 Kensington Gardens-square, Bayswater, London, W.
DE TABLEY, GEORGE, Lord, F.Z.S. Tabley House, Knutsford, Cheshire.
1869. ‡DEVON, The Right Hon. the Earl of, D.C.L. Powderham Castle, near Exeter.
*DEVONSHIRE, WILLIAM, Duke of, K.G., M.A., LL.D., F.R.S., F.G.S., F.R.G.S., Chancellor of the University of Cambridge. Devonshire House, Piccadilly, London, W.; and Chatsworth, Derbyshire.
1868. ‡DEWAR, JAMES, F.R.S.E., Jacksonian Professor of Natural Philosophy in the University of Cambridge.
1872. ‡Dewick, Rev. E. S. The College, Eastbourne, Sussex.
1873. *Dew-Smith, A. G. 7A Eaton-square, London, S.W.
1858. ‡Dibb, Thomas Townend. Little Woodhouse, Leeds.
1852. †DICKIE, GEORGE, M.A., M.D., F.L.S., Professor of Botany in the University of Aberdeen.
1864. *Dickinson, F. H., F.G.S. Kingweston, Somerton, Taunton; and 121 St. George's-square, London, S.W.
1863. ‡Dickinson, G. T. Claremont-place, Newcastle-on-Tyne.
1861. *Dickinson, William Leeson 1 St. James's-street, Manchester.
1867. §DICKSON, ALEXANDER, M.D., Professor of Botany in the University of Glasgow. 11 Royal-circus, Edinburgh.
1868. ‡Dickson, J. Thompson. 33 Harley-street, London, W.
1862. *DILKE, Sir CHARLES WENTWORTH, Bart., M.P., F.R.G.S. 76 Sloane-street, London, S.W.
1848. ‡DILLWYN, LEWIS LLEWELYN, M.P., F.L.S., F.G.S. Parkwern, near Swansea.
1872. §Dines, George. Grosvenor-road, London, S.W.

Year of
Election.

1869. ‡Dingle, Edward. 19 King-street, Tavistock.
1859. *Dingle, Rev. J. Lanchester Vicarage, Durham.
1837. DIRCKS, HENRY, C.E., LL.D., F.C.S. 48 Charing-cross, London, S.W.
1868. ‡Dittmar, W. Andersonian University, Glasgow.
1874. *Dixon, A. E. Dunowen, Cliftonville, Belfast.
1853. ‡Dixon, Edward, M.I.C.E. Wilton House, Southampton.
1865. ‡*Dixon, L.*
1861. ‡DIXON, W. HEPWORTH, F.S.A., F.R.G.S. 6 St. James's-terrace, Regent's-park, London, N.W.
*Dobbin, Leonard, M.R.I.A. 27 Gardiner's-place, Dublin.
1851. ‡Dobbin, Orlando T., LL.D., M.R.I.A. Ballivor, Kells, Co. Meath.
1860. *Dobbs, Archibald Edward, M.A. Richmond-road, Ealing, W.
1864. *Dobson, William. Oakwood, Bathwick Hill, Bath.
Dockray, Benjamin.
1875. *Docwra, George, jun. Grosvenor-road, Handsworth, Birmingham.
1870. *Dodd, John. 6 Thomas-street, Liverpool.
1874. ‡*Dodd, W. H., M.A. Mountjoy-street, Dublin.*
1857. ‡*Dodds, Thomas W., C.E. Rotherham.*
*Dodsworth, Benjamin. Westwood, Scarborough.
*Dodsworth, George. The Mount, York.
Dolphin, John. Delves House, Berry Edge, near Gateshead.
1851. ‡Domvile, William C., F.Z.S. Thorn Hill, Bray, Dublin.
1867. ‡Don, John. The Lodge, Broughty Ferry, by Dundee.
1867. ‡Don, William G. St. Margaret's, Broughty Ferry, by Dundee.
1873. ‡Donham, Thomas. Huddersfield.
1869. ‡Donisthorpe, G. T. St. David's Hill, Exeter.
1871. ‡*Donkin, Arthur Scott, M.D. Sunderland.*
1874. ‡Donnell, Professor, M.A. 28 Upper Sackville-street, Dublin.
1861. ‡Donnelly, Captain, R.E. South Kensington Museum, London, W.
1857. *DONNELLY, WILLIAM, C.B., Registrar-General for Ireland. Charlemont House, Dublin.
1857. ‡Donovan, M., M.R.I.A. Clare-street, Dublin.
1867. ‡Dougall, Andrew Maitland, R.N. Scotscraig, Tayport, Fifeshire.
1871. ‡Dougall, John, M.D. 2 Cecil-place, Paisley-road, Glasgow.
1863. **Doughty, C. Montagu.*
1855. ‡DOVE, HECTOR. Rose Cottage, Trinity, near Edinburgh.
1870. ‡Dowie, J. M. Walstones, West Kirby, Liverpool.
Downall, Rev. John. Okehampton, Devon.
1857. ‡DOWNING, S., LL.D., Professor of Civil Engineering in the University of Dublin. Dublin.
1872. *Dowson, Edward, M.D. 117 Park-street, London, W.
1865. *Dowson, E. Theodore. Geldeston, near Beccles, Suffolk.
1868. §DRESSER, HENRY E., F.Z.S. 6 Tenterden-street, Hanover-square, London, W.
1873. §Drew, Frederick, LL.D., F.G.S. Claremont-road, Surbiton.
1869. §Drew, Joseph, LL.D., F.G.S., F.R.S.C., F.R.S.L. Weymouth.
1865. ‡Drew, Robert A. 6 Stanley-place, Duke-street, Broughton, Manchester.
1872. *Druce, Frederick. 27 Oriental-place, Brighton.
1874. ‡Druitt, Charles. Hampden-terrace, Rugby-road, Belfast.
Drummond, H. Home, F.R.S.E. Blair Drummond, Stirling.
1859. ‡Drummond, Robert. 17 Stratton-street, London, W.
1866. *Dry, Thomas. 23 Gloucester-road, Regent's Park, London, N.W.
1863. ‡*Dryden, James. South Benwell, Northumberland.*
1870. §Drysdale, J. J., M.D. 36A Rodney-street, Liverpool.

Year of Election.

1856. *DUCIE, HENRY JOHN REYNOLDS MORETON, Earl of, F.R.S., F.G.S. 16 Portman-square, London, W.; and Tortworth Court, Wotton-under-Edge.
1870. ‡Duckworth, Henry, F.L.S., F.G.S. 5 Cook-street, Liverpool.
1867. *DUFF, MOUNTSTUART EPHINSTONE GRANT-, LL.B., M.P. 4 Queen's Gate-gardens, South Kensington, London, W.; and Eden, near Banff, Scotland.
1852. ‡Dufferin, The Right Hon. Lord. Highgate, London, N.; and Clandeboye, Belfast.
1875. §Duffin, C. L'Estrange, C.E. Rathkeale, Co. Limerick.
1859. *Duncan, Alexander. 7 Prince's-gate, London, S.W.
1859. ‡Duncan, Charles. 52 Union-place, Aberdeen.
1866. *Duncan, James. 71 Cromwell-road, South Kensington, London, W.
Duncan, J. F., M.D. 8 Upper Merrion-street, Dublin.
1871. ‡Duncan, James Matthew, M.D. 30 Charlotte-square, Edinburgh.
1867. ‡DUNCAN, PETER MARTIN, M.B., F.R.S., F.G.S., Professor of Geology in King's College, London. 99 Abbey-road, St. John's Wood, London, N.W.
Dunlop, Alexander. Clober, Milngavie, near Glasgow.
1853. *Dunlop, William Henry. Annanhill, Kilmarnock, Ayrshire.
1865. ‡Dunn, David. Annet House, Skelmorlie, by Greenock, N.B.
1862. §DUNN, ROBERT, F.R.C.S. 31 Norfolk-street, Strand, London, W.C.
Dunnington-Jefferson, Rev. Joseph, M.A., F.C.P.S. Thicket Hall, York.
1859. ‡Duns, Rev. John, D.D., F.R.S.E. New College, Edinburgh.
1866. ‡Duprey, Perry. Woodbury Down, Stoke Newington, London, N.
1869. ‡D'Urban, W. S. M., F.L.S. 4 Queen-terrace, Mount Radford, Exeter.
1860. ‡DURHAM, ARTHUR EDWARD, F.R.C.S., F.L.S., Demonstrator of Anatomy, Guy's Hospital. 82 Brook-street, Grosvenor-square, London, W.
Dykes, Robert. Kilmorie, Torquay, Devon.
1869. §Dymond, Edward E. Oaklands, Aspley Guise, Woburn.

1868. †Eade, Peter, M.D. Upper St. Giles's-street, Norwich.
1861. ‡Eadson, Richard. 13 Hyde-road, Manchester.
1864. ‡*Earle, Rev. A.*
*EARNSHAW, Rev. SAMUEL, M.A. 14 Broomfield, Sheffield.
1874. §Eason, Charles. 30 Kenilworth-square, Rathgar, Dublin.
1871. *EASTON EDWARD. 7 Delahay-street, Westminster, S.W.
1863. §Easton, James. Nest House, near Gateshead, Durham.
Eaton, Rev. George, M.A. The Pole, Northwich.
1870. §Eaton, Richard. Basford, Nottingham.
Ebden, Rev. James Collett, M.A., F.R.A.S. Great Stukeley Vicarage, Huntingdonshire.
1867. ‡*Eckersley, James.*
1861. ‡Ecroyd, William Farrer. Spring Cottage, near Burnley.
1858. *Eddison, Francis. Martinstown, Dorchester.
1870. *Eddison, Dr. John Edwin. 29 Park-square, Leeds.
*Eddy, James Ray, F.G.S. Carleton Grange, Skipton.
Eden, Thomas. Talbot-road, Oxton.
*EDGEWORTH, MICHAEL P., F.L.S., F.R.A.S. Mastrim House, Anerley, London, S.E.
1855. ‡Edmiston, Robert. Elmbank-crescent, Glasgow.
1859. ‡Edmond, James. Cardens Haugh, Aberdeen.
1870. *Edmonds, F. B. 8 York-place, Northam, Southampton.
1867. *Edward, Allan. Farington Hall, Dundee.

Year of
Election.

1867. ‡Edward, Charles. Chambers, 8 Bank-street, Dundee.
1867. ‡Edward, James. Balruddery, Dundee.
Edwards, John.
1855. *EDWARDS, Professor J. BAKER, Ph.D., D.C.L. Montreal, Canada.
1867. ‡Edwards, William. 70 Princes-street, Dundee.
*EGERTON, Sir PHILIP DE MALPAS GREY, Bart., M.P., F.R.S., F.G.S. Oulton Park, Tarporley, Cheshire.
1859. *Eisdale, David A., M.A. 38 Dublin-street, Edinburgh.
1873. §Elcock, Charles. 39 Lyme-street, Shakspere-street, Ardwick, Manchester.
1868. ‡Elger, Thomas Gwyn Empy, F.R.A.S. St. Mary, Bedford.
Ellacombe, Rev. H. T., F.S.A. Clyst, St. George, Topsham, Devon.
1863. ‡Ellenberger, J. L. Worksop.
1855. §Elliot, Robert, F.B.S.E. Wolfelee, Hawick, N.B.
1861. *ELLIOT, Sir WALTER, K.C.S.I., F.L.S. Wolfelee, Hawick, N.B.
1864. ‡Elliott, E. B. Washington, United States.
1872. ‡Elliott, Rev. E. B. 11 Sussex-square, Kemp Town, Brighton.
Elliott, John Fogg. Elvet Hill, Durham.
1864. *ELLIS, ALEXANDER JOHN, B.A., F.R.S., F.S.A. 25 Argyll-road, Kensington, London, W.
1875. *Ellis, H. D. Fair Park House, Exeter.
1859. ‡ELLIS, HENRY S., F.R.A.S. Fair Park, Exeter.
1864. *Ellis, Joseph. Hampton Lodge, Brighton.
1864. ‡Ellis, J. Walter. High House, Thornwaite, Ripley, Yorkshire.
*Ellis, Rev. Robert, A.M. The Institute, St. Saviour's Gate, York.
1874. §Ellis, Sydney. The Newarke, Leicester.
1869. ‡Ellis, William Horton. Pennsylvania, Exeter.
Ellman, Rev. E. B. Berwick Rectory, near Lewes, Sussex.
1862. ‡Elphinstone, H. W., M.A., F.L.S. Cadogan-place, London, S.W.
Eltoft, William.
1863. ‡Embleton, Dennis, M.D. Northumberland-street, Newcastle-on-Tyne.
1863. ‡Emery, Rev. W., B.D. Corpus Christi College, Cambridge.
1858. ‡Empson, Christopher. Bramhope Hall, Leeds.
1866. ‡Enfield, Richard. Low Pavement, Nottingham.
1866. ‡Enfield, William. Low Pavement, Nottingham.
1871. ‡*Engelson, T. 11 Portland-terrace, Regent's Park, London, N.W.*
1853. ‡English, Edgar Wilkins. Yorkshire Banking Company, Lowgate, Hull.
1869. ‡English, J. T. Stratton, Cornwall.
ENNISKILLEN, WILLIAM WILLOUGHBY, Earl of, D.C.L., F.R.S., M.R.I.A., F.G.S. 65 Eaton-place, London, S.W.; and Florence Court, Fermanagh, Ireland.
1869. ‡Ensor, Thomas. St. Leonards, Exeter.
1869. *Enys, John Davis. Canterbury, New Zealand. (Care of F. G. Enys, Esq., Enys, Penryn, Cornwall.)
1844. ‡Erichsen, John Eric, Professor of Clinical Surgery in University College, London. 9 Cavendish-place, London, W.
1864. *Eskrigge, R. A., F.G.S. 18 Hackins-hey, Liverpool.
1862. *ESSON, WILLIAM, M.A., F.R.S., F.C.S., F.R.A.S. Merton College; and 1 Bradmore-road, Oxford.
Estcourt, Rev. W. J. B. Long Newton, Tetbury.
1869. ‡ETHERIDGE, ROBERT, F.R.S.L. & E., F.G.S., Palæontologist to the Geological Survey of Great Britain. Museum of Practical Geology, Jermyn-street; and 19 Halsey-street, Cadogan-place, London. S.W.

Year of
Election.
1870. *Evans, Arthur John. Nash Mills, Hemel Hempstead.
1865. *EVANS, Rev. CHARLES, M.A. The Rectory, Solihull, Birmingham
1872. *Evans, Frederick J., C.E. Clayponds, Brentford, Middlesex, W.
1869. *Evans, H. Saville W. Wimbledon Park House, Wimbledo S.W.
1861. *EVANS, JOHN, F.R.S., F.S.A., F.G.S. 65 Old Bailey, London, E.C.; and Nash Mills, Hemel Hempstead.
1865. ‡EVANS, SEBASTIAN, M.A., LL.D. Highgate, near Birmingham.
1875. §Evans, Sparke. 3 Apsley-road, Clifton, Bristol.
1866. ‡Evans, Thomas, F.G.S. Belper, Derbyshire.
1865. *Evans, William. Ellerslie, Augustus-road, Edgbaston, Birmingham.
1871. §Eve, H. W. Wellington College, Wokingham, Berkshire.
1868. *EVERETT, J. D., D.C.L., F.R.S.E., Professor of Natural Philosophy in Queen's College, Belfast. Rushmere, Malone-road, Belfast.
1863. *Everitt, George Allen, K.L., K.H., F.R.G.S. Knowle Hall, Warwickshire.
1874. ‡Ewart, William Glenmachan, Belfast.
1874. ‡Ewart, W. Quartus. Glenmachan, Belfast.
1859. *Ewing, Archibald Orr, M.P. Ballikinrain Castle, Killearn, Stirlingshire.
1871. *Exley, John T., M.A. 1 Cotham-road, Bristol.
1846. *Eyre, George Edward, F.G.S., F.R.G.S. 59 Lowndes-square, London, S.W.; and Warren's, near Lyndhurst, Hants.
1866. †EYRE, Major-General Sir VINCENT, F.R.G.S. Athenæum Club, Pall Mall, London, S.W.
Eyton, Charles. Hendred House, Abingdon.
1849. †Eyton, T. C. Eyton, near Wellington, Salop.

1842. Fairbairn, Thomas. Manchester.
1865. ‡Fairley, Thomas, F.R.S.E. 8 Newton-grove, Leeds.
1870. ‡Fairlie, Robert, C.E. Woodlands, Clapham Common, London, S.W.
1864. ‡Falkner, F. H. Lyncombe, Bath.
1859. ‡Farquharson, Robert O. Houghton, Aberdeen.
1861. §FARR, WILLIAM, M.D., D.C.L., F.R.S., Superintendent of the Statistical Department, General Registry Office. Southlands, Bickley, Kent.
1866. *FARRAR, Rev. FREDERICK WILLIAM, D.D., F.R.S., Canon of Westminster. Marlborough College, Wilts.
1857. ‡Farrelly, Rev. Thomas. Royal College, Maynooth.
1869. *Faulconer, R. S. Fairlawn, Clarence-road, Clapham Park, London, S.W.
1869. *Faulding, Joseph. The Grange, Greenhill Park, New Barnet, Herts.
1869. ‡Faulding, W. F. Didsbury College, Manchester.
1859. *FAWCETT, HENRY, M.P., Professor of Political Economy in the University of Cambridge. 51 The Lawn, South Lambeth-road, London, S.W.; and 8 Trumpington-street, Cambridge.
1863. ‡Fawcus, George. Alma-place, North Shields.
1873. *Fazakerley, Miss. The Castle, Denbigh.
1845. ‡Felkin, William, F.L.S. The Park, Nottingham.
Fell, John B. Spark's Bridge, Ulverston, Lancashire.
1864. §FELLOWS, FRANK P., F.S.A., F.S.S. 8 The Green, Hampstead, London, N.W.
1852. ‡Fenton, S. Greame. 9 College-square; and Keswick, near Belfast.
1859. ‡Ferguson, John. Cove, Nigg, Inverness.
1871. *Ferguson, John, M.A., Professor of Chemistry in the University of Glasgow.

Year of Election.

1867. ‡Ferguson, Robert M., Ph.D., F.R.S.E. 8 Queen-street, Edinburgh.
1857. ‡Ferguson, Samuel. 20 North Great George-street, Dublin.
1854. ‡Ferguson, William, F.L.S., F.G.S. Kinmundy, near Mintlaw, Aberdeenshire.
1867. *Fergusson, H. B. 13 Airlie-place, Dundee.
1863. *FERNIE, JOHN. Bonchurch, Isle of Wight.
1862. ‡FERRERS, Rev. N. M., M.A. Caius College, Cambridge.
1873. ‡Ferrier, David, M.D. 23 Somerset-street, Portman-square, London, W.
1875. §Fiddes, Walter. Clapton Villa, Tyndall's Park, Clifton, Bristol.
1868. ‡Field, Edward. Norwich.
1869. *FIELD, ROGERS. 5 Cannon-row, Westminster, S.W.
Fielding, G. H., M.D.
1864. ‡Finch, Frederick George, B.A., F.G.S. 21 Crooms-hill, Greenwich, S.E.
Finch, John. Bridge Work, Chepstow.
Finch, John, jun. Bridge Work, Chepstow.
1863. ‡*Finney, Samuel.*
1868. ‡Firth, G. W. W. St. Giles's-street, Norwich.
Firth, Thomas. Northwick.
1863. *Firth, William. Burley Wood, near Leeds.
1851. *FISCHER, WILLIAM L. F., M.A., LL.D., F.R.S., Professor of Mathematics in the University of St. Andrews. St. Andrews, Scotland.
1858. ‡Fishbourne, Captain E. G., R.N. 6 Welamere-terrace, Paddington, London, W.
1869. ‡FISHER, Rev. OSMOND, M.A., F.G.S. Harlston Rectory, near Cambridge.
1873. §Fisher, William. Maes Fron, near Welshpool, Montgomeryshire.
1875. *Fisher, W. W., M.A., F.C.S. 2 Park-crescent, Oxford.
1858. ‡Fishwick, Henry. Carr-hill, Rochdale.
1871. *Fison, Frederick W., F.C.S. Eastmoor, Ilkley, Yorkshire.
1871. §FITCH, J. G., M.A. 5 Lancaster-terrace, Regent's Park, London, N.W.
1868. ‡Fitch, Robert, F.G.S., F.S.A. Norwich.
1857. ‡Fitzgerald, The Right Hon. Lord Otho. 13 Dominick-street, Dublin.
1857. ‡Fitzpatrick, Thomas, M.D. 31 Lower Bagot-street, Dublin.
Fitzwilliam, Hon. George Wentworth, F.R.G.S. 19 Grosvenor-square, London, S.W.; and Wentworth House, Rotherham.
1865. ‡Fleetwood, D. J. 45 George-street, St. Paul's, Birmingham.
Fleetwood, Sir Peter Hesketh, Bart. Rossall Hall, Fleetwood, Lancashire.
1850. ‡Fleming, Professor Alexander, M.D. 121 Hagley-road, Birmingham.
Fleming, Christopher, M.D. Merrion-square North, Dublin.
Fleming, John G., M.D. 155 Bath-street, Glasgow.
*FLEMING, WILLIAM, M.D. Rowton Grange, near Chester.
1867. §FLETCHER, ALFRED E. 21 Overton-street, Liverpool.
1870. ‡Fletcher, B. Edgington. Norwich.
1853. ‡FLETCHER, ISAAC, F.R.S., F.G.S., F.R.A.S. Tarn Bank, Workington.
1869. ‡FLETCHER, LAVINGTON E., C.E. 41 Corporation-street, Manchester.
Fletcher, T. B. E., M.D. 7 Waterloo-street, Birmingham.
1862. ‡FLOWER, WILLIAM HENRY, F.R.S., F.L.S., F.G.S., F.R.C.S., Hunterian Professor of Comparative Anatomy, and Conservator of the Museum of the Royal College of Surgeons. Royal College of Surgeons, Lincoln's-Inn-fields, London, W.C.
1867. ‡Foggie, William. Woodville, Maryfield, Dundee.

Year of Election.

1854. *FORBES, DAVID, F.R.S., F.G.S., F.C.S. 11 York-place, Portman-square, London, W.
1873. *Forbes, Professor George, M.A., F.R.S.E. Andersonian University, Glasgow.
1855. ‡Forbes, Rev. John. Symington Manse, Biggar, Scotland.
Ford, H. R. Morecombe Lodge, Yealand Conyers, Lancashire.
1866. ‡Ford, William. Hartsdown Villa, Kensington Park-gardens East, London, W.
1875. *Fordham, H. George, F.G.S. Odsey, near Royston, Herts.
*Forrest, William Hutton. The Terrace, Stirling.
1867. ‡Forster, Anthony. Finlay House, St. Leonard's-on-Sea.
1858. *FORSTER, The Right Hon. WILLIAM EDWARD, M.P., F.R.S. Wharfeside, Burley-in-Wharfedale, Leeds.
1871. ‡*Forsyth, William F.*
1854. *Fort, Richard. 24 Queen's-gate-gardens, London, W.; and Read Hall, Whalley, Lancashire.
1870. ‡Forwood, William B. Hopeton House, Seaforth, Liverpool.
1875. §Foster, A. Le Neve. East Hill, Wandsworth, Surrey, S.W.
1865. ‡Foster, Balthazar W., M.D. 4 Old-square, Birmingham.
1865. *FOSTER, CLEMENT LE NEVE, B.A., D.Sc., F.G.S. Truro, Cornwall.
1857. *FOSTER, GEORGE C., B.A., F.R.S., F.C.S., Professor of Physics in University College, London. 12 Hilldrop-road, London, N.
*Foster, Rev. John, M.A. The Oaks Vicarage, Loughborough.
1845. ‡Foster, John N. Sandy Place, Sandy, Bedfordshire.
1859. *FOSTER, MICHAEL, M.A., M.D., F.R.S., F.L.S., F.C.S. (GENERAL SECRETARY.) Trinity College, and Great Shelford, near Cambridge.
1859. §FOSTER, PETER LE NEVE, M.A. Society of Arts, Adelphi, London, W.C.
1873. ‡Foster, Peter Le Neve, jun. Mortara, Italy.
1863. ‡Foster, Robert. 30 Rye-hill, Newcastle-upon-Tyne.
1859. *Foster, S. Lloyd. Old Park Hall, Walsall, Staffordshire.
1873. *Foster, William. Harrowins House, Queensbury, Yorkshire.
1842. Fothergill, Benjamin. 10 The Grove, Boltons, West Brompton, London, S.W.
1870. ‡Foulger, Edward. 55 Kirkdale-road, Liverpool.
1866. §Fowler, George. Basford Hall, near Nottingham.
1868. ‡Fowler, G. G. Gunton Hall, Lowestoft, Suffolk.
1856. ‡Fowler, Rev. Hugh, M.A. College-gardens, Gloucester.
1870. *Fowler, Robert Nicholas, M.A., F.R.G.S. 50 Cornhill, London, E.C.
1868. ‡Fox, Colonel A. H. LANE, F.G.S., F.S.A. Guildford, Surrey.
1842. *Fox, Charles. Trebah, Falmouth.
*Fox, Rev. Edward, M.A. The Vicarage, Romford, Essex.
*Fox, Joseph Hayland. The Cleve, Wellington, Somerset.
1860. ‡Fox, Joseph John. Church-row, Stoke Newington, London, N.
Fox, ROBERT WERE, F.R.S. Falmouth.
1866. *Francis, G. B. 43 Stoke Newington-green, London, N.
FRANCIS, WILLIAM, Ph.D., F.L.S., F.G.S., F.R.A.S. Red Lion-court, Fleet-street, London, E.C.; and Manor House, Richmond, Surrey.
1846. ‡FRANKLAND, EDWARD, D.C.L., Ph.D., F.R.S., F.C.S., Professor of Chemistry in the Royal School of Mines. 14 Lancaster-gate, London, W.
*Frankland, Rev. Marmaduke Charles. Chowbent, near Manchester.
1859. ‡Fraser, George B. 3 Airlie-place, Dundee.
Fraser, James. 25 Westland-row, Dublin.

Year of Election.

Fraser, James William. 8a Kensington Palace-gardens, London, W.
1865. *FRASER, JOHN, M.A., M.D. Chapel Ash, Wolverhampton.
1871. ‡FRASER, THOMAS R., M.D., F.R.S.E. 3 Grosvenor-street, Edinburgh.
1859. *Frazer, Daniel. 113 Buchanan-street, Glasgow.
1871. ‡Frazer, Evan L. R. Brunswick-terrace, Spring Bank, Hull.
1860. ‡Freeborn, Richard Fernandez. 38 Broad-street, Oxford.
1847. *Freeland, Humphrey William, F.G.S. West-street, Chichester, Sussex.
1865. ‡Freeman, James. 15 Francis-road, Edgbaston, Birmingham.
Frere, George Edward, F.R.S. Roydon Hall, Diss.
1869. ‡FRERE, The Right Hon. Sir H. BARTLE E., G.C.S.I., K.G.C.B., F.R.G.S. Wressil Lodge, Wimbledon, S.W.
1869. ‡Frere, Rev. William Edward. The Rectory, Bilton, near Bristol.
Fripp, George, D., M.D.
1857. *Frith, Richard Hastings C.E., M.R.I.A., F.R.G.S.I. 48 Summerhill, Dublin.
1869. ‡Frodsham, Charles. 26 Upper Bedford-place, Russell-square, London, W.C.
1847. ‡Frost, William. Wentworth Lodge, Upper Tulse-hill, London, S.W.
1860. *FROUDE, WILLIAM, M.A., C.E., F.R.S. Chelston Cross, Torquay.
1875. §Fry, F. J. 104 Pembroke-road, Clifton, Bristol.
Fry, Francis. Cotham, Bristol.
1875. *Fry, Joseph Storrs. 2 Charlotte-street, Bristol.
Fry, Richard. Cotham Lawn, Bristol.
Fry, Robert. Tockington, Gloucestershire.
1872. *Fuller, Rev. A. Ichenor, Chichester.
1873. §Fuller, Claude S., R.N. 44 Holland-road, Kensington, W.
1859. ‡FULLER, FREDERICK, M.A., Professor of Mathematics in the University and King's College, Aberdeen.
1869. ‡FULLER, GEORGE, C.E., Professor of Engineering in Queen's College, Belfast. 6 College-gardens, Belfast.
1864. *Furneaux, Rev. Alan. St. German's Parsonage, Cornwall.

*Gadesden, Augustus William, F.S.A. Ewell Castle, Surrey.
1857. ‡Gages, Alphonse, M.R.I.A. Museum of Irish Industry, Dublin.
1863. *Gainsford, W. D. Richmond Hill, Sheffield.
1850. ‡Gairdner, Professor W. F., M.D. 225 St. Vincent-street, Glasgow.
1861. ‡Galbraith, Andrew. Glasgow.
GALBRAITH, Rev. J. A., M.R.I.A. Trinity College, Dublin.
1867. ‡Gale, James M. 33 Miller-street, Glasgow.
1863. ‡Gale, Samuel, F.C.S. 338 Oxford-street, London, W.
1861. ‡Galloway, Charles John. Knott Mill Iron Works, Manchester.
1861. ‡Galloway, John, jun. Knott Mill Iron Works, Manchester.
1875. §Galloway, W., H.M. Inspector of Mines. Cardiff.
1860. *GALTON, Captain DOUGLAS, C.B., D.C.L., F.R.S., F.L.S., F.G.S., F.R.G.S. (GENERAL SECRETARY.) 12 Chester-street, Grosvenor-place, London, S.W.
1860. *GALTON, FRANCIS, F.R.S., F.G.S., F.R.G.S. 42 Rutland-gate, Knightsbridge, London, S.W.
1869. ‡GALTON, JOHN C., M.A., F.L.S. 13 Margaret-street, Cavendish-square, London, W.
1870. §Gamble, Lieut.-Col. D. St. Helen's, Lancashire.
1870. *Gamble, John G. Savile Club, 15 Savile-row, London, W.
1868. ‡GAMGEE, ARTHUR, M.D., F.R.S., F.R.S.E. Owens College, Manchester.
1862 §GARNER, ROBERT, F.L.S. Stoke-upon-Trent.
1865. §Garner, Mrs. Robert. Stoke-upon-Trent.

Year of Election.

1842. Garnett, Jeremiah. Warren-street, Manchester.
1873. ‡Garnham, John. 123 Bunhill-row, London, E.C.
1874. *Garstin, John Ribton, M.R.I.A., F.S.A. Greenhill, Killiney, Co. Dublin.
1870. ‡Gaskell, Holbrook. Woolton Wood, Liverpool.
1870. *Gaskell, Holbrook, jun. Mayfield-road, Aigburth, Liverpool.
1847. *Gaskell, Samuel. Windham Club, St. James's-square, London, S.W.
1842. Gaskell, Rev. William, M.A. Plymouth-grove, Manchester.
1846. ‡GASSIOT, JOHN PETER, D.C.L., LL.D., F.R.S., F.C.S. Clapham Common, London, S.W.
1862. *Gatty, Charles Henry, M.A., F.L.S., F.G.S. Felbridge Park, East Grinstead, Sussex.
1875. §Gavey, J. 21 Shrubbery Park West, Clifton, Bristol.
1875. §Gaye, Henry S. Newton Abbott, Devon.
1873. ‡Geach, R. G. Cragg Wood, Rawdon, Yorkshire.
1871. ‡Geddes, John. 9 Melville-crescent, Edinburgh.
1859. ‡Geddes, William D., M.A., Professor of Greek, King's College, Old Aberdeen.
1854. ‡Gee, Robert, M.D. 5 Abercromby-square, Liverpool.
1867. §GEIKIE, ARCHIBALD, LL.D., F.R.S.L. & E., F.G.S., Director of the Geological Survey of Scotland. Geological Survey Office, Victoria-street, Edinburgh; and Ramsay Lodge, Edinburgh.
1871. §Geikie, James, F.R.S.L. & E., F.G.S. 16 Duncan-terrace, Newington, Edinburgh.
1855. ‡Gemmell, Andrew. 38 Queen-street, Glasgow.
1875. *George, Rev. Hereford B., M.A., F.R.G.S. New College, Oxford.
1854. ‡Gerard, Henry. 8A Rumford-place, Liverpool.
1870. ‡Gerstl, R. University College, London, W.C.
1870. *Gervis, Walter S., M.D. Ashburton, Devonshire.
1856. *Gething, George Barkley. Springfield, Newport, Monmouthshire.
1865. ‡Gibbins, William. Battery Works, Digbeth, Birmingham.
1871. ‡Gibson, Alexander. 19 Albany-street, Edinburgh.
1868. ‡Gibson, C. M. Bethel-street, Norwich.
1874. ‡Gibson, Edward, Q.C. 23 Fitzwilliam-square, Dublin.
*Gibson, George Stacey. Saffron Walden, Essex.
1852. ‡Gibson, James. 35 Mountjoy-square, Dublin.
1870. ‡*Gibson, R. E.*
1870. ‡Gibson, Thomas. 51 Oxford-street, Liverpool.
1870. ‡Gibson, Thomas, jun. 19 Parkfield-road, Prince's Park, Liverpool.
1867. ‡Gibson, W. L., M.D. Tay-street, Dundee.
1842. GILBERT, JOSEPH HENRY, Ph.D., F.R.S., F.C.S. Harpenden, near St. Albans.
1857. ‡Gilbert, J. T., M.R.I.A. Blackrock, Dublin.
1859. *Gilchrist, James, M.D. Crichton House, Dumfries.
Gilderdale, Rev. John, M.A. Walthamstow, Essex, E.
Giles, Rev. William. Netherleigh House, near Chester.
1871. *Gill, David, jun. The Observatory, Aberdeen.
1868. ‡Gill, Joseph. Palermo, Sicily. (Care of W. H. Gill, Esq., General Post Office, St. Martin's-le-Grand, E.C.)
1864. ‡GILL, THOMAS. 4 Sydney-place, Bath.
1861. *Gilroy, George. Hindley Hall, Wigan.
1867. ‡Gilroy, Robert. Craigie, by Dundee.
1867. §GINSBURG, Rev. C. D., D.C.L., LL.D. Binfield, Bracknell, Berkshire.
1869. ‡Girdlestone, Rev. Canon E., M.A. Halberton Vicarage, Tiverton.
1874. *Girdwood, James Kennedy. Old Park, Belfast.
1850. *Gladstone, George, F.C.S., F.R.G.S. 31 Ventnor-villas, Cliftonville, Brighton.

Year of
Election.

1849. *GLADSTONE, JOHN HALL, Ph.D., F.R.S., F.C.S., Fullerian Professor of Chemistry in the Royal Institution. 17 Pembridge-square, Hyde Park, London, W.
1861. *Gladstone, Murray. 36 Wilton-crescent, London, S.W.
1875. *Glaisher, Ernest Henry. 1 Dartmouth-place, Blackheath, London, S.E.
1861. *GLAISHER, JAMES, F.R.S., F.R.A.S. 1 Dartmouth-place, Blackheath, London, S.E.
1871. *GLAISHER, J. W. L., M.A., F.R.S., F.R.A.S. Trinity College, Cambridge.
1853. ‡Gleadon, Thomas Ward. Moira-buildings, Hull.
1870. §Glen, David Corse. 14 Annfield-place, Glasgow.
1859. ‡Glennie, J. S. Stuart. 6 Stone-buildings, Lincoln's-Inn, London, W.C.
1867. ‡Gloag, John A. L. 10 Inverleith-place, Edinburgh.
Glover, George. Ranelagh-road, Pimlico, London, S.W.
1874. §Glover, George T. 30 Donegall-place, Belfast.
Glover, Thomas. Becley Old Hall, Rowsley, Bakewell.
1874. ‡Glover, Thomas. 77 Claverton-street, London, S.W.
1870. ‡Glynn, Thomas R. 1 Rodney-street, Liverpool.
1872. ‡GODDARD, RICHARD. 16 Booth-street, Bradford, Yorkshire.
1852. ‡Godwin, John. Wood House, Rostrevor, Belfast.
1846. ‡GODWIN-AUSTEN, ROBERT A. C., B.A., F.R.S., F.G.S. Chilworth Manor, Guildford.
GOLDSMID, Sir FRANCIS HENRY, Bart., M.P. St. John's Lodge, Regent's Park, London, N.W.
1873. §Goldthorp, Miss R. F. C. Cleckheaton, Bradford, Yorkshire.
1852. ‡Goodbody, Jonathan. Clare, King's County, Ireland.
1870. ‡Goodison, George William, C.E. Gateacre, Liverpool.
1842. *GOODMAN, JOHN, M.D. 8 Leicester-street, Southport.
1865. ‡Goodman, J. D. Minories, Birmingham.
1869. ‡Goodman, Neville. Peterhouse, Cambridge.
1870. *Goodwin, Rev. Henry Albert, M.A., F.R.A.S. Lambourne Rectory, Romford.
1871. ‡Gordon, Joseph. Poynter's-row, Totteridge, Whetstone, London, N.
1840. ‡Gordon, Lewis D. B. Totteridge, Whetstone, London, N.
1857. ‡Gordon, Samuel, M.D. 11 Hume-street, Dublin.
1865. ‡Gore George, F.R.S. 50 Islington-row, Edgbaston, Birmingham.
1870. ‡Gossage, William. Winwood, Woolton, Liverpool.
1875. *Gotch, Francis. Stokes Croft, Bristol.
*Gotch, Rev. Frederick William, LL.D. Stokes Croft, Bristol.
*Gotch, Thomas Henry. Kettering.
1873. §Gott, Charles, M.I.C.E. Parkfield-road, Manningham, Bradford.
1849. ‡Gough, The Hon. Frederick. Perry Hall, Birmingham.
1857. ‡Gough, George S., Viscount. Rathronan House, Clonmel.
1868. §Gould, Rev. George. Unthank-road, Norwich.
GOULD, JOHN, F.R.S., F.L.S., F.R.G.S., F.Z.S. 26 Charlotte-street, Bedford-square, London, W.C.
1854. ‡*Gourlay, Daniel De la C., M.D.*
1873. ‡Gourlay, J. McMillan. 21 St. Andrew's-place, Bradford, Yorkshire.
1967. ‡Gourley, Henry (Engineer). Dundee.
Gowland, James. London-wall, London, E.C.
1873. §Goyder, Dr. D. Manville-crescent, Bradford, Yorkshire.
1861. ‡Grafton, Frederick W. Park-road, Whalley Range, Manchester.
1867. *GRAHAM, CYRIL, F.L.S., F.R.G.S. 9 Cleveland-row, St. James's, London, S.W.
1875. §GRAHAME, JAMES. Auldhouse, Pollokshaw, near Glasgow.
1852. *Grainger, Rev. John, D.D., M.R.I.A. Skerry and Rathcavan Rectory, Broughshane, near Ballymena, Co. Antrim.

Year of Election.

1871. ‡GRANT, Sir ALEXANDER, Bart., M.A., Principal of the University of Edinburgh. 21 Lansdowne-crescent, Edinburgh.
1870. §GRANT, Colonel J. A., C.B., C.S I., F.R.S., F.L.S., F.R.G.S. 7 Park-square West, London, N.W.
1859. ‡Grant, Hon. James. Cluny Cottage, Forres.
1855. *GRANT, ROBERT, M.A., LL D., F.R.S., F.R.A.S., Regius Professor of Astronomy in the University of Glasgow. The Observatory, Glasgow.
1854. ‡GRANTHAM, RICHARD B., C.E., F.G.S. 22 Whitehall-place, London, S.W.
1864. ‡Grantham, Richard F. 22 Whitehall-place, London, S.W.
1874. §Graves, Rev. James, B.A., M.R.I.A. Inisnag Glebe, Stoneyford, Co. Kilkenny.
*Graves, Rev. Richard Hastings, D.D. 31 Raglan-road, Dublin.
1864. *Gray, Rev. Charles. The Vicarage, Blyth, Worksop.
1865. ‡Gray, Charles. Swan-bank, Bilston.
1870. ‡Gray, C. B. 5 Rumford-place, Liverpool.
1857. ‡Gray, Sir John, M.D. Rathgar, Dublin.
1864. ‡Gray, Jonathan. Summerhill House, Bath.
1859. ‡Gray, Rev. J. H. Bolsover Castle, Derbyshire.
1870. §Gray, J. Macfarlane. 10 York-grove, Queen's-road, Peckham, London, S E.
1873. §Gray, William. Belfast.
*GRAY, WILLIAM, F.G.S. Gray's-court, Minster Yard, York.
*GRAY, Colonel William. Farley Hall, near Reading.
1854. *Grazebrook, Henry. Clent Grove, near Stourbridge, Worcestershire.
1866. §Greaves, Charles Augustus, M.B., LL.B. 32 Friar-gate, Derby.
1873. ‡Greaves, James H., C.E. Albert-buildings, Queen Victoria-street, London, E C.
1869. §Greaves, William. Wellington-circus, Nottingham.
1872. §Greaves, William. 2 Raymond-buildings, Gray's Inn, London, W.C.
1872. *Grece, Clair J., LL.D. Redhill, Surrey.
1858. *Greenhalgh, Thomas. Thornydikes, Sharples, near Bolton-le-Moors.
1863. ‡Greenwell, G. E. Poynton, Cheshire.
1875. §Greenwood, Frederick. School of Medicine, Leeds.
1862. *Greenwood, Henry. 32 Castle-street, and The Woodlands, Anfield-road, Anfield, Liverpool.
1849. ‡Greenwood, William. Stones, Todmorden.
1861. *GREG, ROBERT PHILIPS, F.G.S., F.R.A.S. Coles Park, Buntingford, Herts.
1833. Gregg, T. H. 22 Ironmonger-lane, Cheapside, London, E.C.
1860. ‡GREGOR, Rev. WALTER, M.A. Pitsligo, Rosehearty, Aberdeenshire.
1868. ‡Gregory, Charles Hutton, C.E. 1 Delahay-street, Westminster, S.W.
1861. §Gregson, Samuel Leigh. Aigburth-road, Liverpool.
1875. §Grenfell, J. Granville, B.A., F.G.S. 5 Albert-villas, Clifton, Bristol.
*GRESWELL, Rev. RICHARD, M.A., F.R.S., F.R.G.S. 39 St. Giles's-street, Oxford.
1869. ‡GREY, Sir GEORGE, F.R.G.S. Belgrave-mansions, Grosvenor-gardens, London, S.W.
1863. ‡Grey, W. S. Norton, Stockton-on-Tees.
1871. *Grierson, Samuel. Medical Superintendent of the District Asylum, Melrose, N.B.
1859. ‡GRIERSON, THOMAS BOYLE, M.D. Thornhill, Dumfriesshire.

Year of
Election.

1875. §Grieve, David, F.R.S.E. Hobart House, Dalkeith.
1870. ‡Grieve, John, M.D. 21 Lynedock-street, Glasgow.
*Griffin, John Joseph, F.C.S. 22 Garrick-street, London, W.C.
Griffith, Rev. C. T., D.D. Elm, near Frome, Somerset.
1859. *GRIFFITH, GEORGE, M.A., F.C.S. (ASSISTANT GENERAL SECRETARY.) Harrow.
Griffith, George R. Fitzwilliam-place, Dublin.
1868. ‡GRIFFITH, Rev. JOHN, M.A., D.C.L. Findon Rectory, Worthing Sussex.
1870. ‡Griffith, N. R. The Coppa, Mold, North Wales.
1870. ‡Griffith, Rev. Professor. Bowden, Cheshire.
*GRIFFITH, Sir RICHARD JOHN, Bart., LL.D., F.R.S.E., M.R.I.A., F.G.S. 2 Fitzwilliam-place, Dublin.
1847. ‡Griffith, Thomas. Bradford-street, Birmingham.
GRIFFITHS, Rev. JOHN, M.A. Wadham College, Oxford.
1875. §Grignon, James, H.M. Consul at Riga. Riga.
1870. ‡Grimsdale, T. F., M.D. 29 Rodney-street, Liverpool.
1842. Grimshaw, Samuel, M.A. Errwod, Buxton.
1864. ‡GROOM-NAPIER, CHARLES OTTLEY, F.G.S. 18 Elgin-road, St. Peter's Park, London, N.W.
1869. §Grote, Arthur, F.L.S., F.G.S. The Athenæum Club, Pall Mall, London, S.W.
GROVE, The Hon. Sir WILLIAM ROBERT, Knt., M.A., Ph.D., F.R.S. 115 Harley-street, London, W.
1863. *GROVES, THOMAS B., F.C.S. 80 St. Mary-street, Weymouth.
1869. ‡GRUBB, HOWARD, F.R.A.S. 40 Leinster-square, Rathmines, Dublin.
1857. ‡GRUBB, THOMAS, F.R.S., M.R.I.A. 141 Leinster-road, Dublin.
1872. ‡Grüneisen, Charles Lewis, F.R.G.S. 16 Surrey-street, Strand, London, W.C.
Guest, Edwin, M.A., LL.D., F.R.S., F.L.S., F.R.A.S., Master of Caius College, Cambridge. Caius Lodge, Cambridge; and Sandford Park, Oxfordshire.
1867. ‡Guild, John. Bayfield, West Ferry, Dundee.
Guinness, Henry. 17 College-green, Dublin.
1842. Guinness, Richard Seymour. 17 College-green, Dublin.
1856. *GUISE, Sir WILLIAM VERNON, Bart., F.G.S., F.L.S. Elmore Court, near Gloucester.
1862. ‡Gunn, John, M.A., F.G.S. Irstedd Rectory, Norwich.
1866. ‡GÜNTHER, ALBERT C. L. G., M.D., F.R.S. British Museum, London, W.C.
1868. *Gurney, John. Sprouston Hall, Norwich.
1860. *GURNEY, SAMUEL, F.L.S., F.R.G.S. 20 Hanover-terrace, Regent's Park, London, N.W.
*Gutch, John James. Holgate Lodge, York.
1859. ‡GUTHRIE, FREDERICK, B.A., F.R.S.L. & E., F.C.S., Professor of Physics in the Royal School of Mines. 24 Stanley-crescent, Notting Hill, London, W.
1864. §Guyon, George. South Cliff Cottage, Ventnor, Isle of Wight.
1870. ‡*Guyton, Joseph.*
1857. ‡Gwynne, Rev. John. Tullyagnish, Letterkenny, Strabane, Ireland.

Hackett, Michael. Brooklawn, Chapelizod, Dublin.
1865. §Hackney, William. 9 Victoria Chambers, Victoria-street, London, S.W.
1866. *Hadden, Frederick J. 3 Park-terrace, Nottingham.
1866. ‡Haddon, Henry. Lenton Field, Nottingham.

Year of Election.

Haden, G. N. Trowbridge, Wiltshire.
1865. ‡*Haden, W. H.*
1842. Hadfield, George. Victoria-park, Manchester.
1870. ‡Hadivan, Isaac. 3 Huskisson-street, Liverpool.
1848. ‡Hadland, William Jenkins. Banbury, Oxfordshire.
1870. ‡Haigh, George. Waterloo, Liverpool.
*Hailstone, Edward, F.S.A. Walton Hall, Wakefield, Yorkshire.
1869. ‡Hake, R. C. Grasmere Lodge, Addison-road, Kensington, London, W.
1875. §Hale, Rev. Edward, M.A., F.G.S., F.R.G.S. Eton College, Windsor.
1870. ‡Halhead, W. B. 7 Parkfield-road, Liverpool.
HALIFAX, The Right Hon. Viscount. 10 Belgrave-square, London, S.W.; and Hickleston Hall, Doncaster.
1872. ‡Hall, Dr. Alfred. 30 Old Steine, Brighton.
1854. *HALL, HUGH FERGIE, F.G.S. Greenheys, Wallasey, Birkenhead.
1859. ‡Hall, John Frederic. Ellerker House, Richmond, Surrey.
1872. *Hall, Captain Marshall. Scientific Club, Savile-row, London, W.
*Hall, Thomas B. Australia. (Care of J. P. Hall, Esq., Crane House, Great Yarmouth.)
1866. *HALL, TOWNSHEND M., F.G.S. Pilton, Barnstaple.
1860. §Hall, Walter. 10 Pier-road, Erith.
1873. §Hallett, T. G. P., M.A. Bristol.
1868. *HALLETT, WILLIAM HENRY, F.L.S. 10 Percival-terrace, Brighton.
1861. ‡*Halliday, James. Whalley Cottage, Whalley Range, Manchester.*
Halsall, Edward. 4 Somerset-street, Kingsdown, Bristol.
1858. *Hambly, Charles Hambly Burbridge, F.G.S. The Leys, Barrow-on-Soar, near Loughborough.
1866. §HAMILTON, ARCHIBALD, F.G.S. South Barrow, Bromley, Kent.
1865. §Hamilton, Gilbert. Leicester House, Kenilworth-road, Leamington.
HAMILTON, The Very Rev. HENRY PARR, Dean of Salisbury, M.A., F.R.S.L. & E., F.G.S., F.R.A.S. Salisbury.
1869. ‡Hamilton, John, F.G.S. Fyne Court, Bridgewater.
1869. §Hamilton, Roland. Oriental Club, Hanover-square, London, W.
1851. ‡Hammond, C. C. Lower Brook-street, Ipswich.
1863. ‡HANCOCK, ALBANY, F.L.S. 4 St. Mary's-terrace, Newcastle-upon-Tyne.
1875. §Hancock, C. F., jun., M.A. Royal Institution, Albemarle-street, London, W.
1863. ‡Hancock, John. 4 St. Mary's-terrace, Newcastle-on-Tyne.
1850. ‡Hancock, John, J.P. The Manor House, Lurgan, Co. Armagh.
1861. ‡Hancock, Walker. 10 Upper Chadwell-street, Pentonville, London, N.
1857. ‡Hancock, William J. 74 Lower Gardiner-street, Dublin.
1847. ‡HANCOCK, W. NEILSON, LL.D. 74 Lower Gardiner-street, Dublin.
1865. ‡Hands, M. Coventry.
Handyside, P. D., M.D., F.R.S.E. Fairmount, Moffat, Dumfriesshire.
1867. ‡Hannah, Rev. John, D.C.L. The Vicarage, Brighton.
1859. ‡Hannay, John. Montcoffer House, Aberdeen.
1853. ‡Hansell, Thomas T. 2 Charlotte-street, Sculcoates, Hull.
*HARCOURT, A. G. VERNON, M.A., F.R.S., F.C.S. 3 Norham-gardens, Oxford.
Harcourt, Egerton V. Vernon, M.A., F.G.S. Whitwell Hall, Yorkshire.
1865. ‡Harding, Charles. Harborne Heath, Birmingham.
1869. ‡Harding, Joseph. Hill's Court, Exeter.
1869. ‡Harding, William D. Islington Lodge, Kings Lynn, Norfolk.

Year of Election.

1874. ‡Hardman, E. T., F.C.S. 14 Hume-street, Dublin.
1872. ‡Hardwicke, Mrs. 192 Piccadilly, London, W.
*HARE, CHARLES JOHN, M.D., Professor of Clinical Medicine in University College, London. 57 Brook-street, Grosvenor-square, London, W.
Harford, Summers. Haverfordwest.
1858. ‡Hargrave, James. Burley, near Leeds.
1853. §HARKNESS, ROBERT, F.R.S.L. & E., F.G.S., Professor of Geology in Queen's College, Cork.
1871. §Harkness, William. Laboratory, Somerset House, London, W.C.
1875. *Harland, Rev. Albert Augustus, M.A. The Vicarage, Harefield, Middlesex.
1862. *HARLEY, GEORGE, M.D., F.R.S., F.C.S. 25 Harley-street, London, W.
*Harley, John. Ross Hall, near Shrewsbury.
1862. *HARLEY, Rev. ROBERT, F.R.S., F.R.A.S. Mill Hill School, Middlesex; and Burton Bank, Mill Hill, Middlesex, N.W.
1861. ‡Harman, H. W., C.E. 16 Booth-street, Manchester.
1868. *HARMER, F. W., F.G.S. Oakland House, Cringleford, Norwich.
1872. §Harpley, Rev. William, M.A., F.C.P.S. Clayhanger Rectory, Tiverton.
*Harris, Alfred. Oxton Hall, Tadcaster.
*Harris, Alfred, jun. Lunefield, Kirkby-Lonsdale, Westmoreland.
1871. ‡HARRIS, GEORGE, F.S.A. Iselipps Manor, Northolt, Southall, Middlesex.
1863. ‡Harris, T. W. Grange, Middlesborough-on-Tees.
1873. ‡Harris, W. W. Oak-villas, Bradford, Yorkshire.
1860. ‡Harrison, Rev. Francis, M.A. Oriel College, Oxford.
1864. §Harrison, George. Barnsley, Yorkshire.
1873. §Harrison, George, Ph.D., F.L.S., F.C.S. 205 Glossop-road, Sheffield.
1874. §Harrison, G. D. B. 3 Beaufort-road, Clifton, Bristol.
1858. *HARRISON, JAMES PARK, M.A. Cintra Park Villa, Upper Norwood, S.E.
1870. ‡HARRISON, REGINALD. 51 Rodney-street, Liverpool.
1853. ‡Harrison, Robert. 36 George-street, Hull.
1863. ‡Harrison, T. E. Engineers' Office, Central Station, Newcastle-on-Tyne.
1853. *Harrison, William, F.S.A., F.G.S. Samlesbury Hall, near Preston, Lancashire.
1849. ‡HARROWBY, DUDLEY RYDER, Earl of, K.G., D.C.L., F.R.S., F.R.G.S. 39 Grosvenor-square, London, W.; and Sandon Hall, Lichfield.
1859. *Hart, Charles. Harbourne Hall, Birmingham.
1875. §Hart, W. E. Kilberry, near Londonderry.
1856. ‡Hartland, F. Dixon, F.S.A., F.R.G.S. The Oaklands, near Cheltenham.
Hartley, James. Sunderland.
1871. ‡Hartley, Walter Noel. King's College, London, W.C.
1854. §HARTNUP, JOHN, F.R.A.S. Liverpool Observatory, Bidston, Birkenhead.
1850. ‡Harvey, Alexander. 4 South Wellington-place, Glasgow.
1870. ‡Harvey, Enoch. Riversdale-road, Aigburth, Liverpool.
*Harvey, Joseph Charles. Knockrea, Douglas-road, Cork.
Harvey, J. R., M.D. St. Patrick's-place, Cork.
1862. *Harwood, John, jun. Woodside Mills, Bolton-le-Moors.
1875. §Hasting, G. W. Barnard's Green House, Malvern.
Hastings, Rev. H. S. Martley Rectory, Worcester.

Year of
Election.

1837. ‡Hastings, W. Huddersfield.
1842. *Hatton, James. Richmond House, Higher Broughton, Manchester.
1857. ‡HAUGHTON, Rev. SAMUEL, M.D., M.A., F.R.S., M.R.I.A., F.G.S., Professor of Geology in the University of Dublin. Trinity College, Dublin.
*Haughton, William. 28 City Quay, Dublin.
1874. ‡Hawkins, B. Waterhouse, F.L.S., F.G.S. Allison Tower, Dulwich, London, S.E.
Hawkins, John Heywood, M.A., F.R.S., F.G.S. Bignor Park, Petworth, Sussex.
1872. *Hawkshaw, Henry Paul. 20 King-street, St. James's, London, S.W.
*HAWKSHAW, Sir JOHN, C.E., F.R.S., F.G.S. (PRESIDENT.) Hollycombe, Liphook, Petersfield; and 33 Great George-street, London, S.W.
1864. *Hawkshaw, John Clarke, M.A., F.G.S. 25 Cornwall-gardens, South Kensington, S.W.; and 33 Great George-street, London, S.W.
1868. §HAWKSLEY, THOMAS, C.E., F.G.S. 30 Great George-street, London, S.W.
1863. ‡Hawthorn, William. The Cottage, Benwell, Newcastle-upon-Tyne.
1859. ‡Hay, Sir Andrew Leith, Bart. Rannes, Aberdeenshire.
1861. *HAY, Rear-Admiral the Right Hon. Sir JOHN C. D., Bart., C.B., M.P., F.R.S. 108 St. George's-square, London, S.W.
1858. ‡Hay, Samuel. Albion-place, Leeds.
1867. ‡Hay, William. 21 Magdalen-yard-road, Dundee.
1857. ‡Hayden, Thomas, M.D. 30 Harcourt-street, Dublin.
1873. *Hayes, Rev. William A., B.A. 61 George-street, Leeds.
1869. ‡Hayward, J. High-street, Exeter.
1858. *HAYWARD, ROBERT BALDWIN, M.A. The Park, Harrow.
1851. §HEAD, JEREMIAH, C.E., F.S.S. Middlesbrough, Yorkshire.
1869. ‡Head, R. T. The Briars, Alphington, Exeter.
1869. ‡Head, W. R. Bedford-circus, Exeter.
1863. ‡Heald, Joseph. 22 Leazes-terrace, Newcastle-on-Tyne.
1872. ‡Healey, C. E. H. Chadwyck. 8 Albert-mansions, Victoria-street, London, S.W.
1871. §Healey, George. Matson's, Windermere.
1861. *Heape, Benjamin. Northwood, Prestwich, near Manchester.
1865. ‡Hearder, William. Victoria Parade, Torquay.
1866. ‡Heath, Rev. D. J. Esher, Surrey.
1863. ‡Heath, G. Y., M.D. Westgate-street, Newcastle-on-Tyne.
1861. §HEATHFIELD, W. E., F.C.S., F.R.G.S., F.R.S.E. 20 King-street St. James's, London, S.W.
1865. ‡Heaton, Harry. Harborne House, Harborne, near Birmingham.
1858. *HEATON, JOHN DEAKIN, M.D., F.R.C.P. Claremont, Leeds.
1865. ‡Heaton, Ralph. Harborne Lodge, near Birmingham.
1833. ‡HEAVISIDE, Rev. CANON J. W. L., M.A. The Close, Norwich.
1855. ‡HECTOR, JAMES, M.D., F.R.S., F.G.S., F.R.G.S., Geological Survey of New Zealand. Wellington, New Zealand.
1867. ‡HEDDLE, M. FOSTER, M.D., Professor of Chemistry in the University of St. Andrews, N.B.
1869. ‡Hedgeland, Rev. W. J. 21 Mount Radford, Exeter.
1863. ‡Hedley, Thomas. Cox Lodge, near Newcastle-on-Tyne.
1862. ‡*Helm, George F.*
1857. *Hemans, George William, C.E., M.R.I.A., F.G.S. 1 Westminster-chambers, Victoria-street, London, S.W.
1867. ‡Henderson, Alexander. Dundee.

Year of Election.

1845. ‡Henderson, Andrew. 120 Gloucester-place, Portman-square, London, W.
1873. *Henderson, A. L. 49 King William-street, London, E.C.
1866. ‡*Henderson, James, jun. Dundee.*
1874. §Henderson, James Alexander. Norwood Tower, Belfast.
1873. *HENDERSON, W. D. 12 Victoria-street, Belfast.
1856. ‡HENNESSY, HENRY G., F.R.S., M.R.I.A., Professor of Applied Mathematics in the Royal College of Science for Ireland. Mount Eagle, Sandyford, Co. Dublin.
1857. ‡Hennessy, John Pope, Governor of the Bahamas. Government House, Nassau.
1873. *Henrici, Olaus M. F. E., Ph.D., F.R.S., Professor of Mathematics in University College, London. 22 Torriano-avenue, Camden Town, London, N.W.
Henry, Franklin. Portland-street, Manchester.
Henry, J. Snowdon. East Dene, Bonchurch, Isle of Wight.
Henry, Mitchell, M.P. Stratheden House, Hyde Park, London, W.
1874. ‡HENRY, Rev. P. SHULDAM, D.D., M.R.I.A. President, Queen's College, Belfast.
*HENRY, WILLIAM CHARLES, M.D., F.R.S., F.G.S., F.R.G.S. Haffield, near Ledbury, Herefordshire.
1870. ‡Henty, William. Norfolk-terrace, Brighton.
1855. *Hepburn, J. Gotch, LL.B., F.C.S. Sidcup-place, Sidcup, Kent.
1855. ‡Hepburn, Robert. 9 Portland-place, London, W.
Hepburn, Thomas. Clapham, London, S.W.
1871. ‡Hepburn, Thomas H. St. Mary's Cray, Kent.
Hepworth, John Mason. Ackworth, Yorkshire.
1856. ‡Hepworth, Rev. Robert. 2 St. James's-square, Cheltenham.
*Herbert, Thomas. The Park, Nottingham.
1852. ‡*Herdman, John.*
1866. §Herrick, Perry. Bean Manor Park, Loughborough.
1871. *HERSCHEL, Professor ALEXANDER S., B.A., F.R.A.S. College of Science, Newcastle-on-Tyne.
1874. ‡Herschel, Captain John, R.E., F.R.S. Collingwood, Hawkhurst, Kent.
1865. ‡Heslop, Dr. Birmingham.
1863. ‡*Heslop, Joseph.*
1873. ‡Heugh, John. Gaunt's House, Wimborne, Dorset.
1832. ‡Hewitson, William C. Oatlands, Surrey.
Hey, Rev. William, M.A., F.C.P.S. Clifton, York.
1866. *Heymann, Albert. West Bridgford, Nottinghamshire.
1866. ‡Heymann, L. West Bridgford, Nottinghamshire.
1861. *Heywood, Arthur Henry. Elleray, Windermere.
*HEYWOOD, JAMES, F.R.S., F.G.S., F.S.A., F.R.G.S., F.S.S. 26 Kensington Palace-gardens, London, W.
1861 *Heywood, Oliver. Claremont, Manchester.
1875. §Hicks, Henry, F.G.S. Heriot House, Hendon, Middlesex, N.W.
Heywood, Thomas Percival. Claremont, Manchester.
1864. *HIERN, W. P., M.A. 1 Foxton-villas, Richmond, Surrey.
1854. **Higgin, Edward.*
1861. *Higgin, James. Lancaster-avenue, Fennel-street, Manchester.
Higginbotham, Samuel. 4 Springfield-court, Queen-street, Glasgow.
1866. ‡Higginbottom, John, F.R.S., F.R.C.S. Gill-street, Nottingham.
1875. §Higgins, Charles Hayes, M.D., M.R.C.P., F.R.C.S., F.R.S.E. Alfred House, Birkenhead.
1871. ‡HIGGINS, CLEMENT, B.A., F.C.S. 27 St. John's-park, Upper Holloway, London, N.

Year of Election.

1861. ‡*Higgins, George.*
1854. ‡HIGGINS, Rev. HENRY H., M.A. The Asylum, Rainhill, Liverpool.
1861. *Higgins, James. Stocks House, Cheetham, Manchester.
1870. ‡HIGGINSON, ALFRED. 44 Upper Parliament-street, Liverpool.
Hildyard, Rev. James, B.D., F.C.P.S. Ingoldsby, near Grantham, Lincolnshire.
Hill, Arthur. Bruce Castle, Tottenham, London, N.
1872. §Hill, Charles. Rockhurst, West Hoathley, East Grinstead.
*Hill, Rev. Edward, M.A., F.G.S. Sheering Rectory, Harlow.
1857. §Hill, John, M.I.C.E., M.R.I.A., F.R.G.S.I. County Surveyor's Office, Ennis, Ireland.
1871. ‡Hill, Lawrence. The Knowe, Greenock.
*HILL, Sir ROWLAND, K.C.B., D.C.L., F.R.S., F.R.A.S. Hampstead, London, N.W.
1864. ‡Hill, William. Combe Hay, Bristol.
1863. ‡Hills, F. C. Chemical Works, Deptford, Kent, S.E.
1871. §Hills, Graham H., Staff-Commander R.N. 4 Bentley-road, Princes Park, Liverpool.
1871. *Hills, Thomas Hyde. 338 Oxford-street, London, W.
1858. ‡HINCKS, Rev. THOMAS, B.A., F.R.S. Stancliff House, Clevedon, Somerset.
1870. ‡Hinde, G. J. Buenos Ayres.
Hindley, Rev. H. J. Edlington, Lincolnshire.
*Hindmarsh, Luke. Alnbank House, Alnwick.
1865. ‡Hinds, James, M.D. Queen's College, Birmingham.
1863. ‡Hinds, William, M.D. Parade, Birmingham.
1861. *Hinmers, William. Cleveland House, Birkdale, Southport.
1858. §Hirst, John, jun. Dobcross, near Manchester.
1861. *HIRST, T. ARCHER, Ph.D., F.R.S., F.R.A.S. Royal Naval College, Greenwich, S.E.; and Athenæum Club, Pall Mall, London, S.W.
1856. ‡Hitch, Samuel, M.D. Sandywell Park, Gloucestershire.
1870. ‡Hitchman, William, M.D., LL.D., F.L.S., &c. 29 Erskine-street, Liverpool.
*Hoare, Rev. George Tooker. Godstone Rectory, Redhill.
Hoare, J. Gurney. Hampstead, London, N.W.
1864. ‡Hobhouse, Arthur Fane. 24 Cadogan-place, London, S.W.
1864. ‡Hobhouse, Charles Parry. 24 Cadogan-place, London, S.W.
1864. ‡Hobhouse, Henry William. 24 Cadogan-place, London, S.W.
1863. §Hobson, A. S., F.C.S. 3 Upper Heathfield-terrace, Turnham Green, London, W.
1866. ‡HOCKIN, CHARLES, M.D. 8 Avenue-road, St. John's Wood, London, N.W.
1852. ‡Hodges, John F., M.D., F.C.S., Professor of Agriculture in Queen's College, Belfast.
1863. *HODGKIN, THOMAS. Benwell Dene, Newcastle-on-Tyne.
1873. *Hodgson, George. Thornton-road, Bradford, Yorkshire.
1873. ‡Hodgson, James. Oakfield, Manningham, Bradford, Yorkshire.
1875. *Hodgson, Kirkman Daniel, M.P. 67 Brook-street, London, W.
1863. ‡Hodgson, Robert. Whitburn, Sunderland.
1863. ‡Hodgson, R. W. North Dene, Gateshead.
1839. ‡Hodgson, W. B., LL.D., F.R.A.S. 41 Grove-end-road, St. John's Wood, London, N.W.
1865. *HOFMANN, AUGUSTUS WILLIAM, LL.D., Ph.D., F.R.S., F.C.S. 10 Dorotheen Strasse, Berlin.
1860. ‡Hogan, Rev. A. R., M.A. Watlington Vicarage, Oxfordshire.

Year of Election

1854. *Holcroft, George. Byron's-court, St. Mary's-gate, Manchester.
1873. *Holden, Isaac. Oakworth House, near Keighley, Yorkshire.
1856. ‡Holland, Henry. Dumbleton, Evesham.
1858. §Holland, Loton, F.R.G.S. The Gables, Osborne-road, Windsor.
*Holland, Philip H. 41 Parliament-street, Westminster, S.W.
1865. ‡Holliday, William. New-street, Birmingham.
1866. *Holmes, Charles. 59 London-road, Derby.
1873. ‡Holmes, J. R. Southbrook Lodge, Bradford, Yorkshire.
1870. ‡Holt, William D. 23 Edge-lane, Liverpool.
*Hone, Nathaniel, M.R.I.A. Bank of Ireland, Dublin.
1875. *Hood, John. The Elms, Cotham Hill, Bristol.
1847. ‡Hooker, Joseph Dalton, C.B., M.D., D.C.L., LL.D., Pres. R.S., V.P.L.S., F.G.S., F.R.G.S. Royal Gardens, Kew, W.
1865. *Hooper, John P. The Hut, Mitcham Common, Surrey.
1861. §Hooper, William. 7 Pall Mall East, London, S.W.
1856. ‡Hooton, Jonathan. 80 Great Ducie-street, Manchester.
1842. Hope, Thomas Arthur. Stanton, Bebington, Cheshire.
1869. ‡Hope, William, V.C. Parsloes, Barking, Essex.
1865. ‡Hopkins, J. S. Jesmond Grove, Edgbaston, Birmingham.
1870. *Hopkinson, John. Woodlea, Beech-lanes, Birmingham.
1871. §Hopkinson, John, F.G.S., F.R.M.S. Holly Bank, Watford.
1858. ‡Hopkinson, Joseph, jun. Britannia Works, Huddersfield.
Hornby, Hugh. Sandown, Liverpool.
1875. *Horniman, F. J. Surrey House, Forest Hill, London, S.E.
1854. ‡Horsfall, Thomas Berry. Bellamour Park, Rugeley.
1856. ‡Horsley, John H. 1 Ormond-terrace, Cheltenham.
Hotham, Rev. Charles, M.A., F.L.S. Roos, Patrington, Yorkshire.
1868. ‡Hotson, W. C. Upper King-street, Norwich.
1859. ‡*Hough, Joseph.*
Houghton, The Right Hon. Lord, M.A., D.C.L., F.R.S., F.R.G.S. 16 Upper Brook-street, London, W.
Houghton, James. 41 Rodney-street, Liverpool.
1858. ‡Hounsfield, James. Hemsworth, Pontefract.
Hovenden, W. F., M.A. Bath.
1859. ‡Howard, Captain John Henry, R.N. The Deanery, Lichfield.
1863. ‡Howard, Philip Henry. Corby Castle, Carlisle.
1857. ‡Howell, Henry H., F.G.S. Museum of Practical Geology, Jermyn-street, London, S.W.
1868. ‡Howell, Rev. Canon Hinds. Drayton Rectory, near Norwich.
1865. *Howlett, Rev. Frederick, F.R.A.S. East Tisted Rectory, Alton, Hants.
1863. ‡Howorth, H. H. Derby House, Eccles, Manchester.
1854. ‡Howson, The Very Rev. J. S., D.D., Dean of Chester. Chester.
1870. ‡Hubback, Joseph. 1 Brunswick-street, Liverpool.
1835. *Hudson, Henry, M.D., M.R.I.A. Glenville, Fermoy, Co. Cork.
1842. §Hudson, Robert, F.R.S., F.G.S., F.L.S. Clapham Common, London, S.W.
1867. ‡Hudson, William H. H., M.A. 19 Bennett's-hill, Doctors' Commons, London, E.C.; and St. John's College, Cambridge.
1858. *Huggins, William, D.C.L. Oxon., LL.D. Camb., F.R.S., F.R.A.S. Upper Tulse-hill, Brixton, London, S.W.
1857. ‡Huggon, William. 30 Park-row, Leeds.
Hughes, D. Abraham.
1871. *Hughes, George Pringle, J. P. Middleton Hall, Wooler, Northumberland.
1870. *Hughes, Lewis. Fenwick-court, Liverpool.

Year of Election.

1868. §HUGHES, T. M'K., M.A., F.G.S., Woodwardian Professor of Geology in the University of Cambridge.
1863. ‡Hughes, T. W. 4 Hawthorn-terrace, Newcastle-on-Tyne.
1865. ‡Hughes, W. R., F.L.S., Treasurer of the Borough of Birmingham. Birmingham.
Hull, Arthur H. 18 Norfolk-road, Brighton.
1867. §HULL, EDWARD, M.A., F.R.S., F.G.S. Director of the Geological Survey of Ireland, and Professor of Geology in the Royal College of Science. 14 Hume-street, Dublin.
*Hull, William Darley. Stenton Lodge, Tunbridge Wells.
*Hulse, Sir Edward, Bart., D.C.L. 47 Portland-place, London, W.; and Breamore House, Salisbury.
1861. ‡HUME, Rev. ABRAHAM, D.C.L., LL.D., F.S.A. All Souls' Vicarage, Rupert-lane, Liverpool.
1856. ‡Humphries, David James. 1 Keynsham-parade, Cheltenham.
1862. *HUMPHRY, GEORGE MURRAY, M.D., F.R.S., Professor of Anatomy in the University of Cambridge. Grove Lodge, Cambridge.
1863. *HUNT, AUGUSTUS H., M.A., Ph.D. Birtley House, near Chester-le-Street.
1865. ‡Hunt, J. P. Gospel Oak Works, Tipton.
1840. ‡HUNT, ROBERT, F.R.S., Keeper of the Mining Records. Museum of Practical Geology, Jermyn-street, London, S.W.
1864. ‡Hunt, W. 72 Pulteney-street, Bath.
1875. *Hunt, William. The Woodlands, Tyndall's Park, Clifton, Bristol.
Hunter, Andrew Galloway. Denholm, Hawick, N.B.
1868. ‡Hunter, Christopher. Alliance Insurance Office, North Shields.
1867. ‡Hunter, David. Blackness, Dundee.
1869. *Hunter, Rev. Robert, F.G.S. 9 Mecklenburgh-street, London, W.C.
1855. *Hunter, Thomas O. 13 William-street, Greenock.
1863. ‡Huntsman, Benjamin. West Retford Hall, Retford.
1875. §Hurnard, James. Lexden, Colchester, Essex.
1869. ‡Hurst, George. Bedford.
1861. *Hurst, William John. Drumaness Mills, Ballynahinch, Lisburn, Ireland.
1870. ‡Hurter, Dr. Ferdinand. Appleton, Widnes, near Warrington.
Husband, William Dalla. Coney-street, York.
1874. ‡Hutchinson, Thomas J., F.R.G.S. Chimoo Cottage, Mill Hill, London, N.W.
1868. *Hutchison, Robert, F.R.S.E. Carlowrie, Kirkliston, N.B.
1863. ‡HUTT, The Right Hon. Sir W., K.C.B. Gibside, Gateshead.
Hutton, Crompton. Putney-park, Surrey, S.W.
1864. *Hutton, Darnton. (Care of Arthur Lupton, Esq., Headingley near Leeds.)
Hutton, Henry. Edenfield, Dundrum, Co. Dublin.
1857. ‡Hutton, Henry D. 10 Lower Mountjoy-street, Dublin.
1861. *Hutton, T. Maxwell. Summerhill, Dublin.
1852. ‡HUXLEY, THOMAS HENRY, Ph.D., LL.D., Sec. R.S., F.L.S., F.G.S., Professor of Natural History in the Royal School of Mines. 4 Marlborough-place, London, N.W.
Hyde, Edward. Dukinfield, near Manchester.
1871. *Hyett, Francis A. 13 Hereford-square, Old Brompton, London, S.W.
Hyett, William Henry, F.R.S. Painswick, near Stroud, Gloucestershire.

Ihne, William, Ph.D. Heidelberg.
1873. §Ikin, J. T. 19 Park-place, Leeds.
1861. ‡Iles, Rev. J. H. Rectory, Wolverhampton.

Year of Election.
1858. ‡Ingham, Henry. Wortley, near Leeds.
1871. ‡INGLIS, The Right Hon. JOHN, D.C.L., LL.D., Lord Justice General of Scotland. Edinburgh.
1858. *Ingram, Hugo Francis Meynell. Temple Newsam, Leeds.
1852. ‡INGRAM, J. K., LL.D., M.R.I.A., Regius Professor of Greek. Trinity College, Dublin.
1870. *Inman, William. Upton Manor, Liverpool.
Ireland, R. S., M.D. 121 Stephen's-green, Dublin.
1857. ‡Irvine, Hans, M.A., M.B. 1 Rutland-square, Dublin.
1862. ‡ISELIN, J. F., M.A., F.G.S. 52 Stockwell Park-road, London, S.W.
1863. *Ivory, Thomas. 23 Walker-street, Edinburgh.

1865. ‡Jabet, George. Wellington-road, Handsworth, Birmingham.
1870. ‡Jack, James. 26 Abercromby-square, Liverpool.
1859. ‡Jack, John, M.A. Belhelvie-by-Whitecairns, Aberdeenshire.
1866. ‡Jackson, H. W., F.R.A.S., F.G.S. 15 The Terrace, High-road Lewisham, S.E.
1869. §Jackson, Moses. The Vale, Ramsgate.
Jackson, Professor Thomas, LL.D. St. Andrew's, Scotland.
1863. *Jackson-Gwilt, Mrs. H. Moonbeam Villa, The Grove, New Wimbledon, London, S.W.
1852. ‡JACOBS, BETHEL. 40 George-street, Hull.
1874. *Jaffe, John. Messrs. Jaffe Brothers, Belfast.
1865. *Jaffray, John. Park-grove, Edgbaston, Birmingham.
1872. ‡James, Christopher. 8 Laurence Pountney Hill, London, E.C.
1859. ‡James, Edward. 9 Gascoyne-terrace, Plymouth.
1860. ‡James, Edward H. 9 Gascoyne-terrace, Plymouth.
JAMES, Major-General Sir HENRY, R.E., F.R.S., F.G.S., M.R.I.A. Topographical Depôt, 4 New-street, London, S.W.
1863. *JAMES, Sir WALTER, Bart., F.G.S. 6 Whitehall-gardens, London, S.W.
1875. §James, Rev. William. Harley Lodge, Clifton, Bristol.
1858. ‡James, William C. 9 Gascoyne-terrace, Plymouth.
1863. ‡*Jameson, John Henry.* 10 *Catherine Terrace, Gateshead.*
1859. *Jamieson, Thomas F., F.G.S. Ellon, Aberdeenshire.
1850. ‡Jardine, Alexander. Jardine Hall, Lockerby, Dumfriesshire.
1870. ‡Jardine, Edward. Beach Lawn, Waterloo, Liverpool.
1853. *Jarratt, Rev. Canon J., M.A. North Cave, near Brough, Yorkshire.
JARRETT, Rev. THOMAS, M.A., Professor of Arabic in the University of Cambridge. Trunch, Norfolk.
1870. §Jarrold, John James. London-street, Norwich.
1862. ‡Jeakes, Rev. James, M.A. 54 Argyll-road, Kensington, W.
Jebb, Rev. John. Peterstow Rectory, Ross, Herefordshire.
1868. ‡Jecks, Charles. 26 Langham-place, Northampton.
1870. ‡*Jeffery, F. J.*
1856. ‡Jeffery, Henry, M.A. 438 High-street, Cheltenham.
1855. *Jeffray, John. Cardowan House, Millerston, Glasgow.
1867. ‡Jeffreys, Howel, M.A., F R.A.S. 5 Brick-court, Temple, E.C.; and 25 Devonshire-place, Portland-place, London, W.
1861. *JEFFREYS, J. GWYN, LL.D., F.R.S., F.L.S., Treas. G.S., F.R.G.S. Ware Priory, Herts.
1852. ‡JELLETT, Rev. JOHN H., M.A., M.R.I.A., Professor of Natural Philosophy in Trinity College, Dublin. 64 Upper Leeson-street, Dublin.
1842. Jellicorse, John. Chaseley, near Rugeley, Staffordshire.

Year of Election.

1862. §JENKIN, H. C. FLEEMING, F.R.S., M.I.C.E., Professor of Civil Engineering in the University of Edinburgh. 3 Great Stuart-street, Edinburgh.
1864. §JENKINS, Captain GRIFFITH, C.B., F.R.G.S. Little Garth, Welshpool.
1873. §Jenkins, Major General J. J. 14 St. James's-square, London, S.W.
*Jenkyns, Rev. Henry, D.D. The College, Durham.
Jennette, Matthew. 106 Conway-street, Birkenhead.
1852. ‡Jennings, Francis M., F.G.S., M.R.I.A. Brown-street. Cork.
1872. ‡Jennings, W. Grand Hotel, Brighton.
1870. ‡Jerdon, T. C. (Care of Mr. H. S. King, 45 Pall Mall, London, S.W.)
*Jerram, Rev. S. John, M.A. Chobham Vicarage, near Bagshot, Surrey.
1872. §Jesson, Thomas. 7 Upper Wimpole-street, Cavendish-square, London, W.
Jessop, William, jun. Butterley Hall, Derbyshire.
1870. *JEVONS, W. STANLEY, M.A., LL.D., F.R.S., Professor of Logic and Political Economy in Owens College, Manchester. 36 Parsonage-road, Withington, Manchester.
1872. *Joad, George C. Oakfield, Wimbledon, Surrey, S.W.
1871. *Johnson, David, F.C.S., F.G.S. Irvon Villa, Grosvenor-road, Wrexham.
1865. *Johnson, G. J. 36 Waterloo-street, Birmingham.
1875. §Johnson, James Henry, F.G.S. 3 Queen's-road, Southport.
1866. §Johnson, John. Knighton Fields, Leicester.
1866. ‡Johnson, John G. 18A Basinghall-street, London, E.C.
1868. ‡Johnson, J. Godwin. St. Giles's-street, Norwich.
1872. ‡Johnson, J. T. 27 Dale-street, Manchester.
1861. ‡Johnson, Richard. 27 Dale-street, Manchester.
1870. §Johnson, Richard C. Warren Side, Blundell Sands, Liverpool.
1863. ‡Johnson, R. S. Hanwell, Fence Houses, Durham.
*Johnson, Thomas. The Hermitage, Frodsham, Cheshire.
1864. ‡*Johnson, Thomas.*
Johnson, William. The Wynds Point, Colwall, Malvern, Worcestershire.
1861. ‡Johnson, William Beckett. Woodlands Bank, near Altrincham.
1871. ‡Johnston, A. Keith, F.R.G.S. 1 Savile-row, London, W.
1864. ‡Johnston, David. 13 Marlborough-buildings, Bath.
1864. ‡*Johnston, Edward.*
1859. ‡Johnston, James. Newmill, Elgin, N.B.
1864. ‡Johnston, James. Manor House, Northend, Hampstead, London, N.W.
*Johnstone, James. Alva House, by Stirling, N.B.
1864. ‡Johnstone, John. 1 Barnard-villas, Bath.
1864. ‡Jolly, Thomas. Park View-villas, Bath.
1871. §Jolly, William (H.M. Inspector of Schools). Inverness, N.B.
1849. ‡Jones, Baynham. Selkirk Villa, Cheltenham.
1856. ‡Jones, C. W. 7 Grosvenor-place, Cheltenham.
1854. ‡*Jones, Rev. Henry H.*
1854. ‡*Jones, John.*
1864. §JONES, JOHN, F.G.S. Saltburn-by-the-Sea, Yorkshire.
1865. ‡Jones, John. 49 Union-passage, Birmingham.
*Jones, Robert. 2 Castle-street, Liverpool.
1873. ‡Jones, Theodore B. 1 Finsbury-circus, London, E.C.
1860. ‡JONES, THOMAS RUPERT, F.R.S., F.G.S., Professor of Geology and Mineralogy, Royal Military and Staff Colleges, Sandhurst. 5 College-terrace, York Town, Surrey.

Year of Election.

1847. ‡JONES, THOMAS RYMER, F.R.S. 52 Cornwall-road, Westbourne Park, London, W.
1864. §JONES, Sir WILLOUGHBY, Bart., F.R.G.S. Cranmer Hall, Fakenham, Norfolk.
1875. *Jose, J. E. 3 Queen-square, Bristol.
*Joule, Benjamin St. John B. 28 Leicester-street, uthport, Lancashire.
1842. *JOULE, JAMES PRESCOTT, LL.D., F.R.S., F.C.S. 343 Lower Broughton-road, Manchester.
1847. ‡JOWETT, Rev. B., M.A., Regius Professor of Greek in the University of Oxford. Balliol College, Oxford.
1858. ‡Jowett, John. Leeds.
1872. ‡Joy, Algernon. 17 Parliament-street, Westminster, S.W.
1848. *Joy, Rev. Charles Ashfield. Grove Parsonage, Wantage, Berkshire.
Joy, Henry Holmes, LL.D., Q.C., M.R.I.A. Torquay.
Joy, Rev. John Holmes, M.A. 3 Coloney-terrace, Tunbridge Wells.
*Jubb, Abraham. Halifax.
1870. ‡Judd, John Wesley, F.G.S. 6 Manor-view, Brixton, London, S.W.
1863. ‡Jukes, Rev. Andrew. Spring Bank, Hull.

1868. *Kaines, Joseph, M.A., D.Sc. 8 Osborne-road, Stroud Green-lane, Hornsey, London, N.
KANE, Sir ROBERT, M.D., F.R.S., M.R.I.A., Principal of the Royal College of Cork. 51 Stephen's-green, Dublin.
1857. ‡Kavanagh, James W. Grenville, Rathgar, Ireland.
1859. ‡Kay, David, F.R.G.S. 19 Upper Phillimore-place, Kensington, London, W.
Kay, John Cunliff. Fairfield Hall, near Skipton.
*Kay, John Robinson. Walmersley House, Bury, Lancashire.
Kay, Robert. Haugh Bank, Bolton-le-Moors.
1847. *Kay, Rev. William, D.D. Great Leghs Rectory, Chelmsford.
1856. ‡Kay-Shuttleworth, Sir James, Bart. Gawthorpe, Burnley.
1872. ‡Keames, William M. 5 Lower-rock-gardens, Brighton.
1855. ‡*Keddie, William.*
1875. §Keeling, George William. Tuthill, Sydney.
1866. ‡Keene, Alfred. Eastnoor House, Leamington.
1850. ‡KELLAND, Rev. PHILIP, M.A., F.R.S. L. & E., Professor of Mathematics in the University of Edinburgh. 20 Clarendon-crescent, Edinburgh.
1864. *Kelly, W. M., M.D. 11 The Crescent, Taunton, Somerset.
1853. ‡Kemp, Rev. Henry William, B.A. The Charter House, Hull.
1875. §Kennedy, Alexander B. W., C.E., Professor of Engineering in University College, London. 9 Bartholomew-road, London, N.W.
1857. ‡Kennedy, Lieut-Colonel John Pitt. 20 Torrington-square, Bloomsbury, London, W.C.
Kenny, Matthias. 3 Clifton-terrace, Monkstown, Co. Dublin.
1865. ‡Kenrick, William. Norfolk-road, Edgbaston, Birmingham.
Kent, J. C. Levant Lodge, Earl's Croome, Worcester.
1857. ‡Kent, William T., M.R.D.S. 51 Rutland-square, Dublin.
1857. ‡Kenworth, James Ryley. 7 Pembroke-place, Liverpool.
1857. *Ker, André Allen Murray. Newbliss House, Newbliss, Ireland.
1855. *Ker, Robert. Auchinraith, by Bothwell, Scotland.
1868. ‡Kerrison, Roger. Crown Bank, Norwich.
1869. *Kesselmeyer, Charles A. 1 Peter-street, Manchester.
1869. *Kesselmeyer, William Johannes. 1 Peter-street, Manchester.

Year of Election.

1861. *Keymer, John. Parker-street, Manchester.
1865. *Kinahan, Edward Hudson. 11 Merrion-square North, Dublin.
1860. ‡Kinahan, G. Henry, M.R.I.A., Geological Survey of Ireland. 14 Hume-street, Dublin.
1858. ‡Kincaid, Henry Ellis, M.A. 8 Lyddon-terrace, Leeds.
1875. *Kinch, Edward, F.C.S. 12 Wellington-street, Islington, London, N.
1872. *King, Mrs. E. M. 34 Cornwall-road, Westbourne-park, London, W.
1875. *King, F. Ambrose. Avonside, Clifton Down, Bristol.
1871. *King, Herbert Poole. Theological College, Salisbury.
1855. ‡King, James. Levernholme, Hurlet, Glasgow.
1870. §King, John Thomson, C.E. 4 Clayton-square, Liverpool.
King, Joseph. Blundell Sands, Liverpool.
1864. §King, Kelburne, M.D. 27 George-street, and Royal Institution, Hull.
1860. *King, Mervyn Kersteman. 16 Vyvyan-terrace, Clifton, Bristol.
1875. *King, Percy L. Avonside, Clifton Down, Bristol.
1842. King, Richard, M.D. 12 Bulstrode-street, London, W.
King, Rev. Samuel, M.A., F.R.A.S. St. Aubins, Jersey.
1870. ‡King, William. 13 Adelaide-terrace, Waterloo, Liverpool.
King, William Poole, F.G.S. Avonside, Clifton, Bristol.
1869. ‡Kingdon, K. Taddiford, Exeter.
1861. ‡Kingsley, John. Ashfield, Victoria Park, Manchester.
1835. Kingstone, A. John, M.A. Mosstown, Longford, Ireland.
1875. §Kingzett, Charles T., F.C.S. 23 Shaftesbury-terrace, Warwick-road, Kensington, London, W.
1867. ‡Kinloch, Colonel. Kirriemuir, Logie, Scotland.
1867. *Kinnaird, The Hon. Arthur Fitzgerald, M.P. 1 Pall Mall East, London, S.W.; and Rossie Priory, Inchture, Perthshire.
1863. ‡Kinnaird, The Right Hon. Lord., K.T., F.G.S. Rossie Priory, Inchture, Perthshire.
Kinnear, J. G., F.R.S.E.
1870. ‡Kinsman, William R. Branch Bank of England, Liverpool.
1863. ‡Kirkaldy, David. 28 Bartholomew-road North, London, N.W.
1860. ‡Kirkman, Rev. Thomas P., M.A., F.R.S. Croft Rectory, near Warrington.
Kirkpatrick, Rev. W. B., D.D. 48 North Great George-street, Dublin.
1875. §Kirsop, John. 6 Queen's-crescent, Glasgow.
1870. ‡Kitchener, Frank E. Rugby.
1869. ‡Knapman, Edward. The Vineyard, Castle-street, Exeter.
1870. §Kneeshaw, Henry. 2 Gambier-terrace, Liverpool.
1836. Knipe, J. A. Botcherby, Carlisle.
1872. *Knott, George, LL.B., F.R.A.S. Cuckfield, Hayward's Heath, Sussex.
1873. *Knowles, George. Moorhead, Shipley, Yorkshire.
1872. ‡Knowles, James. The Hollies, Clapham Common, S.W.
1842. Knowles, John. Old Trafford Bank House, Old Trafford, Manchester.
1870. ‡*Knowles, Rev. J. L.*
1874. §Knowles, William James. Cullybackey, Belfast, Ireland.
*Knox, George James. 2 Portland-terrace, Regent's Park, London, N.W.
1835. Knox, Thomas B. Union Club, Trafalgar-square, London, W.C.
1875. *Knubley, E. P. Steeple Ashton Vicarage, Trowbridge.
1870. ‡Kynaston, Josiah W. St. Helens, Lancashire.
1865. ‡Kynnersley, J. C. S. The Leveretts, Handsworth, Birmingham.

Year of Election.

1858. §Lace, Francis John. Stone Gapp, Cross-hill, Leeds.
1862. ‡*Lackerstein, Dr.*
1859. §Ladd, William, F.R.A.S. 11 & 13 Beak-street, Regent-street, London, W.
1850. ‡Laing, David, F.S.A. Scotl. Signet Library, Edinburgh.
1870. ‡Laird, H. H. Birkenhead.
Laird, John, M.P. Hamilton-square, Birkenhead.
1870. §Laird, John, jun. Grosvenor-road, Claughton, Birkenhead.
1859. ‡Lalor, John Joseph, M.R.I.A. 2 Longford-terrace, Monkstown, Co. Dublin.
1846. *Laming, Richard. Flansham, near Bognor, Sussex.
1870. ‡Lamport, Charles. Upper Norwood, Surrey, S.E.
1871. §Lancaster, Edward. Karesforth Hall, Barnsley, Yorkshire.
1859. ‡Lang, Rev. John Marshall. Bank House, Morningside, Edinburgh.
1864. §Lang, Robert. Mancombe, Henbury, Bristol.
1870. ‡Langton, Charles. Barkhill, Aigburth, Liverpool.
*Langton, William. Manchester and Salford Bank, Manchester.
1865. §LANKESTER, E. RAY, M.A., F.R.S., Professor of Comparative Anatomy and Zoology in University College, London. Exeter College, Oxford.
Lanyon, Sir Charles. The Abbey, White Abbey, Belfast.
*LARCOM, Major-General Sir THOMAS AISKEW, Bart., K.C.B., R.E., F.R.S., M.R.I.A. Heathfield House, Fareham, Hants.
LASSELL, WILLIAM, F.R.S., F.R.A.S. Ray Lodge, Maidenhead.
1861. *Latham, Arthur G. Lower King-street, Manchester.
1870. *Latham, Baldwin. 7 Westminster-chambers, Westminster, S.W.
1870. ‡Laughton, John Knox, M.A., F.R.A.S., F.R.G.S. Royal Naval College, Portsmouth.
1875. §Lavington, William F. 107 Pembroke-road, Clifton, Bristol.
1870. *Law, Channell. 5 Champion-park, Camberwell, London, S.E.
1857. ‡Law, Hugh, Q.C. 4 Great Denmark-street, Dublin.
1862. ‡Law, Rev. James Edmund, M.A. Little Shelford, Cambridgeshire.
Lawley, The Hon. Francis Charles. Escrick Park, near York.
Lawley, The Hon. Stephen Willoughby. Escrick Park, near York.
1870. ‡Lawrence, Edward. Aigburth, Liverpool.
1875. §Lawson, George, Ph.D., LL.D., Professor of Chemistry and Botany. Halifax, Nova Scotia.
1869. ‡Lawson, Henry. 8 Nottingham-place, London, W.
1857. ‡Lawson, The Right Hon. James A., LL.D., M.R.I.A. 27 Fitzwilliam-street, Dublin.
1868. *LAWSON, M. ALEXANDER, M.A., F.L.S., Professor of Botany in the University of Oxford. Botanic Gardens, Oxford.
1863. ‡Lawton, Benjamin C. Neville Chambers, 44 Westgate-street, Newcastle-upon-Tyne.
1853. ‡Lawton, William. 5 Victoria-terrace, Derringham, Hull.
LAYCOCK, THOMAS, M.D., Professor of the Practice of Physic in the University of Edinburgh. 4 Rutland-street, Edinburgh.
1865. ‡Lea, Henry. 35 Paradise-street, Birmingham.
1857. ‡Leach, Capt. R. E. Mountjoy, Phœnix Park, Dublin.
1870. *Leaf, Charles John, F.L.S., F.G.S., F.S.A. Old Change, London, E.C.; and Painshill, Cobham.
1847. *LEATHAM, EDWARD ALDAM, M.P. Whitley Hall, Huddersfield; and 46 Eaton-square, London, S.W.
*Leather, John Towlerton, F.S.A. Leventhorpe Hall, near Leeds.
1858. ‡Leather, John W. Newton Green, Leeds.
1863. ‡Leavers, J. W. The Park, Nottingham.

Year of Election.

1872. ‡LEBOUR, G. A., F.G.S. Weedpark House, Dipton, Lintz Green, Co. Durham.
1858. *Le Cappelain, John. Wood-lane, Highgate, London, N.
1858. ‡Ledgard, William. Potter Newton, near Leeds.
1842. Lee, Daniel. Springfield House, Pendlebury, Manchester.
1861. ‡Lee, Henry. Irwell House, Lower Broughton, Manchester.
1853. *LEE, JOHN EDWARD, F.G.S., F.S.A. Villa Syracusa, Torquay.
1859. ‡Lees, William. Link Vale Lodge, Viewforth, Edinburgh.
*Leese, Joseph. Glenfield, Altrincham, Manchester.
*Leeson, Henry B., M.A., M.D., F.R.S., F.C.S The Maples, Bonchurch, Isle of Wight.
1872. ‡LEFEVRE, G. SHAW, M.P., F.R.G.S. 18 Spring-gardens, London, S.W.
*LEFROY, Major-General J. HENRY, C.B., R.A., F.R.S., F.R.G.S., Governor of Bermuda. Bermuda.
*Legh, Lieut.-Colonel George Cornwall, M.P. High Legh Hall, Cheshire; and 43 Curzon-street, Mayfair, London, W.
1869. ‡Le Grice, A. J. Trereife, Penzance.
1868. ‡LEICESTER, The Right Hon. the Earl of. Holkham, Norfolk.
1856. ‡LEIGH, The Right Hon. Lord, D.C.L. 37 Portman-square, London, W.; and Stoneleigh Abbey, Kenilworth.
1861. *Leigh, Henry. Moorfield, Swinton, near Manchester.
1870. ‡Leighton, Andrew. 35 High-park-street, Liverpool.
1867. §Leishman, James. Gateacre Hall, Liverpool.
1870. ‡Leister, G. F. Gresbourn House, Liverpool.
1859. ‡Leith, Alexander. Glenkindie, Inverkindie, N.B.
1863. *LENDY, Capt. AUGUSTE FREDERIC, F.L.S., F.G.S. Sunbury House, Sunbury, Middlesex.
1867. ‡Leng, John. 'Advertiser' Office, Dundee.
1861 ‡Lennox, A. C. W. 7 Beaufort-gardens, Brompton, London, S.W.
Lentaigne, John, M.D. Tallaght House, Co. Dublin; and 14 Great Dominick-street, Dublin.
Lentaigne, Joseph. 12 Great Denmark-street, Dublin.
1871. §LEONARD, HUGH, M.R.I.A., Geological Survey of Ireland. 14 Hume-street, Dublin.
1874. ‡Lepper, Charles W. Laurel Lodge, Belfast.
1861. ‡Leppoc, Henry Julius. Kersal Crag, near Manchester.
1872. §Lermit, Rev. Dr. School House, Dedham.
1871. ‡Leslie, Alexander, C.E. 72 George-street, Edinburgh.
1856. ‡Leslie, Colonel J. Forbes. Rothienorman, Aberdeenshire.
1852. ‡LESLIE, T. E. CLIFFE, LL.B., Professor of Jurisprudence and Political Economy, Queen's College, Belfast.
1866. §LEVI, Dr. LEONE, F.S.A., F.S.S., F.R.G.S., Professor of Commercial Law in King's College, London. 5 Crown Office-row, Temple, London, E.C.
1870. ‡Lewis, Alfred Lionel. 151 Church-road, De Beauvoir Town, London, N.
1853. ‡Liddell, George William Moore. Sutton House, near Hull.
1860. ‡LIDDELL, The Very Rev. H. G., D.D., Dean of Christ Church, Oxford.
1855. ‡*Liddell, John.*
1859. ‡*Ligertwood, George.*
1864. ‡LIGHTBODY, ROBERT, F.G.S. Ludlow, Salop.
1862. ‡LILFORD, The Right Hon. Lord, F.L.S. Lilford Hall, Oundle, Northamptonshire.
*LIMERICK, CHARLES GRAVES, D.D., M.R.I.A., Lord Bishop of. The Palace, Henry-street, Limerick.
*Lindsay, Charles. Ridge Park, Lanark, N.B.

Year of
Election.

1855. **Lindsay, John H.*
1871. *LINDSAY, The Right Hon. Lord, M.P. 47 Brook-street, London, W.
1871. ‡Lindsay, Rev. T. M. 7 Great Stuart-street, Edinburgh.
1870. ‡Lindsay, Thomas. 288 Renfrew-street, Glasgow.
1842 *Lingard, John R., F.G.S. Mayfield, Shortlands, Bromley, Kent.
Lingwood, Robert M., M.A., F.L.S., F.G.S. 1 Derby-villas, Cheltenham.
Lister, James. Liverpool Union Bank, Liverpool.
1873. *Lister, Samuel Cunliffe. Farfield Hall, Addingham, Leeds.
1870. §Lister, Thomas. Victoria-crescent, Barnsley.
Littledale, Harold. Liscard Hall, Cheshire.
1861. *LIVEING, G. D., M.A., F.C.S., Professor of Chemistry in the University of Cambridge. Cambridge.
1864. §Livesay, J. G. Cromarty House, Ventnor, Isle of Wight.
1860. ‡Livingstone, Rev. Thomas Gott, Minor Canon of Carlisle Cathedral.
Lloyd, Rev. A. R. Hengold, near Oswestry.
Lloyd, Rev. C., M.A. Whittington, Oswestry.
1842. Lloyd, Edward. King-street, Manchester.
1865. ‡Lloyd, G. B. Edgbaston-grove, Birmingham.
*Lloyd, George, M.D., F.G.S. Park Glass Works, Birmingham.
*LLOYD, Rev. HUMPHREY, D.D., LL.D., F.R.S. L. & E., M.R.I.A., Provost of Trinity College, Dublin.
1870. ‡Lloyd, James. 16 Welfield-place, Liverpool.
1870. ‡Lloyd, J. H., M.D. Anglesey, North Wales.
1865. ‡Lloyd, John. Queen's College, Birmingham.
Lloyd, Rev. Rees Lewis. Belper, Derbyshire.
1865. *Lloyd, Wilson. Myrod House, Wednesbury.
1854. *LOBLEY, JAMES LOGAN, F.G.S., F.R.G.S. 59 Clarendon-road, Kensington, London, W.
1853. *Locke, John. (Care of J. Robertson, Esq., 3 Grafton-street, Dublin.)
1867. *Locke, John. 83 Addison-road, Kensington, London, W.
1872. ‡LOCKE, JOHN, M.P. 63 Eaton-place, London, S.W.
1863. ‡LOCKYER, J. NORMAN, F.R.S., F.R.A.S. 5 Alexandra-road, Finchley-road, London, N.W.
1875. *Lodge, Oliver J. Hanley, Staffordshire.
1868. ‡Login, Thomas, C.E., F.R.S.E. India.
1862. ‡Long, Andrew, M.A. King's College, Cambridge.
1872. ‡Long, Jeremiah. 50 Marine Parade, Brighton.
1871. *Long, John Jex. 727 Duke-street, Glasgow.
1851. ‡Long, William, F.G.S. Hurts Hall, Saxmundham, Suffolk.
1866. §Longdon, Frederick. Luamdur, near Derby.
1857. ‡Longfield, Rev. George, D.D. Trinity College, Dublin.
LONGFIELD, MOUNTIFORT, LL.D., M.R.I.A., Regius Professor of Feudal and English Law in the University of Dublin. 47 Fitzwilliam-square, Dublin.
1861. *Longman, William, F.G.S. 36 Hyde Park-square, London, W.
1859. ‡Longmuir, Rev. John, M.A., LL.D. 14 Silver-street, Aberdeen.
Longridge, William S. Boyne Grove, Maidenhead, Berks.
1875. *Longstaff, George Blundell, B.A., F.C.S. Southfield Grange, Wandsworth, S.W.
1871. §Longstaff, George Dixon, M.D., F.C.S. Southfields, Wandsworth, S.W.; and 9 Upper Thames-street, London, E.C.
1872. *Longstaff, Major Llewellyn Wood, F.R.G.S. Summergangs, Hull.
1875. §Lonsdale, N. Lowenthal. The Firs, Westbury Park, Redlands, Bristol.
1861. *Lord, Edward. Adamroyd, Todmorden.

Year of Election.

1863. ‡Losh, W. S. Wreay Syke, Carlisle.
1875. *Lovett, W. J. 96 Lionel-street, Birmingham.
1867. *Low, James F. Monifieth, by Dundee.
1863. *Lowe, Lieut.-Colonel Arthur S. H., F.R.A.S. 76 Lancaster-gate, London, W.
1861. *LOWE, EDWARD JOSEPH, F.R.S., F.R.A.S., F.L.S., F.G.S., F.M.S Highfield House Observatory, near Nottingham.
1870. ‡Lowe, G. C. 67 Cecil-street, Greenheys, Manchester.
1868. ‡Lowe, John, M.D. King's Lynn.
1850. ‡Lowe, William Henry, M.D., F.R.S.E. Balgreen, Slateford, Edinburgh.
1853. *LUBBOCK, Sir JOHN, Bart., M.P., F.R.S., F.L.S., F.G.S. High Elms, Farnborough, Kent.
1870. ‡Lubbock, Montague. High Elms, Farnborough, Kent.
1849. *Luckcock, Howard. Oak-hill, Edgbaston, Birmingham.
1875. §Lucy, W. C., F.G.S. The Winstones, Brookthorpe, Gloucester.
1867. *Luis, John Henry. Cidhmore, Dundee.
1873. ‡Lumley, J. Hope Villa, Thornbury, near Bradford, Yorkshire.
1866. *Lund, Charles. 1 Blenheim-road, Bradford, Yorkshire.
1873. ‡Lund, Joseph. St. George's-place, Bradford, Yorkshire.
1873. ‡Lund, Joseph. St. George's-place, Bradford, Yorkshire.
1850. *Lundie, Cornelius. Tweed Lodge, Charles-street, Cardiff.
1853. ‡Lunn, William Joseph, M.D. 23 Charlotte-street, Hull.
1858. *Lupton, Arthur. Headingley, near Leeds.
1864. *Lupton, Darnton. The Harehills, near Leeds.
1874. *Lupton, Sydney. The Harehills, near Leeds.
1864. *Lutley, John. Brockhampton Park, Worcester.
1866. ‡LYCETT, Sir FRANCIS. 18 Highbury-grove, London, N.
1871. ‡Lyell, Leonard. 42 Regent's Park-road, London, N.W.
1874. §Lynam, James, C.E. Ballinasloe, Ireland.
1857. ‡Lyons, Robert D., F.R.C.P.I. 8 Merrion-square West, Dublin.
1862. *Lyte, F. Maxwell, F.C.S. 6 Cité de Retiro, Faubourg St. Honoré, Paris.

1852. ‡MacAdam, Robert. 18 College-square East, Belfast.
1854. *MACADAM, STEVENSON, Ph.D., F.R.S.E., F.C.S., Lecturer on Chemistry. Surgeons' Hall, Edinburgh; and Brighton House, Portobello, by Edinburgh.
1868. ‡MACALISTER, ALEXANDER, M.D., Professor of Zoology in the University of Dublin. 13 Adelaide-road, Dublin.
1868. ‡M‘Allan, W. A. Norwich.
1866. *M‘Arthur, A., M.P. Raleigh Hall, Brixton Rise, London, S.W.
1840. Macaulay, James A. M., M.D. 22 Cambridge-road, Kilburn, London, N.W.
1871. ‡M‘Bain, James, M.D., R.N. Logie Villa, York-road, Trinity, Edinburgh.
*MacBrayne, Robert. Messrs. Black and Wingate, 5 Exchange-square, Glasgow.
1866. ‡M‘CALLAN, Rev. J. F., M.A. Basford, near Nottingham.
1855. ‡*M‘Callum, Archibald K., M.A.*
1863. ‡M‘Calmont, Robert. Gatton Park, Reigate.
1855. ‡M‘Cann, Rev. James, D.D., F.R.S.L., F.G.S. 18 Shaftesbury-terrace, Glasgow.
1840. M‘Clelland, James, F.S.S. 32 Pembridge-square, London, W.
1868. ‡M‘CLINTOCK, Rear-Admiral Sir FRANCIS L., R.N., F.R.S., F.R.G.S. United Service Club, Pall Mall, London, S.W.
1872. *McClure, J. H. 10 Esplanade, Waterloo, Liverpool.

Year of Election.

1874. ‡M‘Clure, Sir Thomas, Bart. Belmont, Belfast.
*M‘Connel, James. Moore-place, Esher, Surrey.
1859. *M‘Connell, David C., F.G.S. 44 Manor-place, Edinburgh.
1858. ‡M‘Connell, J. E. Woodlands, Great Missenden.
1871. ‡M‘Donald, William. Yokohama, Japan. (Care of R. K. Knevitt, Esq., Sun-court, Cornhill, E.C.)
MacDonnell, Hercules H. G. 2 Kildare-place, Dublin.
*McEwan, John. 9 Melville-terrace, Stirling, N.B.
1859. ‡Macfarlane, Alexander. 73 Bon Accord-street, Aberdeen.
1871. §M‘Farlane, Donald. The College Laboratory, Glasgow.
1855. *Macfarlane, Walter. 22 Park-circus, Glasgow.
1854. *MACFIE, ROBERT ANDREW. 13 Victoria-street, Westminster, S.W.
1867. *M‘Gavin, Robert. Ballumbie, Dundee.
1855. ‡MacGeorge, Andrew, jun. 21 St. Vincent-place, Glasgow.
1872. ‡McGeorge, Mungo. Nithodale, Laurie-park, Sydenham, S.E.
1873. ‡McGowen, William Thomas. Oak-avenue, Oak Mount, Bradford, Yorkshire.
1855. ‡M‘Gregor, Alexander Bennett. 19 Woodside-crescent, Glasgow.
1855. ‡*MacGregor, James Watt. Wallace-grove, Glasgow.*
1859. ‡M‘Hardy, David. 54 Netherkinkgate, Aberdeen.
1859. ‡Macintosh, John. Middlefield House, Woodside, Aberdeen.
1874. ‡MacIlwaine, Rev. William, D.D. Ulsterville, Belfast.
1867. *McINTOSH, W. C., M.D., F.L.S. Murthly, Perthshire.
1854. *MacIver, Charles. 8 Water-street, Liverpool.
1871. §Mackay, Rev. A., LL.D., F.R.G.S. 2 Hatton-place, Grange, Edinburgh.
1873. ‡McKENDRICK, JOHN G., M.D., F.R.S.E. 2 Chester-street, Edinburgh.
1855. ‡M‘Kenzie, Alexander. 89 Buchanan-street, Glasgow.
*Mackenzie, James. Glentore, by Glasgow.
1865. ‡Mackeson, Henry B., F.G.S. Hyde, Kent.
1872. *Mackey, J. A. 24 Buckingham-place, Brighton.
1867. §MACKIE, SAMUEL JOSEPH, F.G.S. 84 Kensington Park-road, London, W.
*Mackinlay, David. Great Western-terrace, Hillhead, Glasgow.
1865. ‡Mackintosh, Daniel, F.G.S. 36 Derby-road, Higher Tranmere, Birkenhead.
1850. ‡Macknight, Alexander. 12 London-street, Edinburgh.
1867. §Mackson, H. G. 25 Cliff-road, Woodhouse, Leeds.
1872. *McLACHLAN, ROBERT, F.L.S. 39 Limes-grove, Lewisham, S.E.
1873. ‡McLandsborough, John, C.E., F.R.A.S., F.G.S. Shipley, near Bradford, Yorkshire.
1860. ‡Maclaren, Archibald. Summertown, Oxfordshire.
1864. §MACLAREN, DUNCAN, M.P. Newington House, Edinburgh.
1873. ‡MacLaren, Walter S. B. Newington House, Edinburgh.
1859. ‡MACLEAR, Sir THOMAS, F.R.S., F.R.G.S., F.R.A.S., late Astronomer Royal at the Cape of Good Hope. Cape Town, South Africa.
1862. ‡Macleod, Henry Dunning. 17 Gloucester-terrace, Campden-hill-road, London, W.
1868. §M‘LEOD, HERBERT, F.C.S. Indian Civil Engineering College, Cooper's Hill, Egham.
1875. §Macliver, D. 1 Broad-street, Bristol.
1875. §Macliver, P. S. 1 Broad-street, Bristol,
1861. *Maclure, John William. 2 Bond-street, Manchester.
1862. ‡Macmillan, Alexander. Streatham-lane, Upper Tooting, Surrey.
1874. §MacMordie, Hans, M.A. 8 Donegall-street, Belfast.
1871. ‡M‘Nab, William Ramsay, M.D., Professor of Botany in the Royal College of Science, Dublin. 4 Vernon-parade, Clontarf, Dublin.

Year of Election.

1870. ‡Macnaught, John, M.D. 74 Huskisson-street, Liverpool.
1867. §M'Neill, John. Balhousie House, Perth.
MacNeill, The Right Hon. Sir John, G.C.B., F.R.S.E., F.R.G.S. Granton House, Edinburgh.
MacNeill, Sir John, LL.D., F.R.S., M.R.I.A. 17 The Grove, South Kensington, London, S.W.
1859. ‡*Macpherson, Rev. W. Kilmuir Easter, Scotland.*
1852. *Macrory, Adam John. Duncairn, Belfast.
*Macrory, Edmund, M.A. 40 Leinster-square, Bayswater, London, W.
1855. ‡M'Tyre, William, M.D. Maybole, Ayrshire.
1855. ‡Macvicar, Rev. John Gibson, D.D., LL.D. Moffat, N.B.
1868. ‡Magnay, F. A. Drayton, near Norwich.
1875. §Magnus, Philip. 2 Portsdown-road, London, W.
Magor, J. B. Redruth, Cornwall.
1869. §Main, Rev. R., F.R.S., F.R.A.S., Director of the Radcliffe Observatory, Oxford.
1869. ‡*Main, Robert. Admiralty, Somerset House, W.C.*
1866. §Major, Richard Henry, F.S.A., F.R.G.S. British Museum, London, W.C.
*Malahide, The Right Hon. Lord Talbot de, M.A., F.R.S., F.G.S., F.S.A. Malahide Castle, Co. Dublin.
*Malcolm, Frederick. Mordon College, Blackheath, London, S.E.
1870. *Malcolm, Sir James, Bart. The Priory, St. Michael's Hamlet, Aigburth, Liverpool.
1874. §Malcolmson, A. B. Friends' Institute, Belfast.
1863. ‡Maling, C. T. Lovaine-crescent, Newcastle-on-Tyne.
1857. ‡Mallet, Dr. John William, F.C.S., Professor of Chemistry in the University of Virginia, U. S.
*Mallet, Robert, Ph.D., F.R.S., F.G.S., M.R.I.A. The Grove, Clapham-road, Clapham; and 7 Westminster-chambers, Victoria-street, London, S.W.
1846. ‡Manby, Charles, F.R.S., F.G.S. 60 Westbourne-terrace, Hyde Park, London, W.
1870. ‡Manifold, W. H. 45 Rodney-street, Liverpool.
1866. §Mann, Robert James, M.D., F.R.A.S. 5 Kingsdown-villas, Wandsworth Common, S.W.
Manning, His Eminence Cardinal. 8 York-place, Portman-square, London, W.
1866. ‡Manning, John. Waverley-street, Nottingham.
1864. ‡Mansel, J. C. Long Thorns, Blandford.
1870. ‡Marcoartu, Senor Don Arturo de. Madrid.
1864. ‡Markham, Clements R., C.B., F.R.S., F.L.S., F.R.G.S., F.S.A. 21 Eccleston-square, Pimlico, London, S.W.
1863. ‡Marley, John. Mining Office, Darlington.
*Marling, Samuel S., M.P. Stanley Park, Stroud, Gloucestershire.
1871. §Marreco, A. Friere-. College of Physical Science, Newcastle-on-Tyne.
Marriott, John.
1857. §Marriott, William, F.C.S. Grafton-street, Huddersfield.
1842. Marsden, Richard. Norfolk-street, Manchester.
1870. ‡Marsh, John. Rann Lea, Rainhill, Liverpool.
1865. ‡Marsh, J. F. Hardwick House, Chepstow.
1856. ‡*Marsh, M. H.*
1864. ‡Marsh, Thomas Edward Miller. 37 Grosvenor-place, Bath.
1852. ‡Marshall, James D. Holywood, Belfast.
1858. ‡Marshall, Reginald Dykes. Adel, near Leeds.
1849. *Marshall, William P. 6 Portland-road, Edgbaston, Birmingham.

Year of Election.
1865. §MARTEN, EDWARD BINDON. Pedmore, near Stourbridge.
1848. ‡Martin, Henry D. 4 Imperial-circus, Cheltenham.
1871. ‡Martin, Rev. Hugh, M.A. Greenhill-cottage, Lasswade by Edinburgh.
1870. ‡Martin, Robert, M.D. 120 Upper Brook-street, Manchester.
1836. Martin, Studley. 177 Bedford-street South, Liverpool.
1867. *Martin, William, jun. 3 Airlie-place, Dundee.
*Martindale, Nicholas. Berryarbor, Ilfracombe.
*Martineau, Rev. James, LL.D., D.D. 5 Gordon-street, Gordon-square, London, W.C.
1865. ‡Martineau, R. F. Highfield-road, Edgbaston, Birmingham.
1865. ‡Martineau, Thomas. 7 Cannon-street, Birmingham.
1875. §Martyn, Samuel, M.D. 8 Buckingham-villas, Clifton, Bristol.
1847. ‡MASKELYNE, NEVIL STORY, M.A., F.R.S., F.G.S., Keeper of the Mineralogical Department, British Museum; and Professor of Mineralogy in the University of Oxford. 112 Gloucester-terrace, Hyde-park-gardens, London, W.
1861. *Mason, Hugh. Groby Lodge, Ashton-under-Lyne.
1868. ‡Mason, James Wood, F.G.S. The Indian Museum, Calcutta. (Care of Messrs. Henry S. King & Co., 65 Cornhill, London, E.C.)
Massey, Hugh, Lord. Hermitage, Castleconnel, Co. Limerick.
1870. ‡Massey, Thomas. 5 Gray's-Inn-square, London, W.C.
1870. ‡Massy, Frederick. 50 Grove-street, Liverpool.
1865. *Mathews, G. S. Portland-road, Edgbaston, Birmingham.
1861. *MATHEWS, WILLIAM, M.A., F.G.S. 49 Harborne-road, Birmingham.
1865. ‡Matthews, C. E. Waterloo-street, Birmingham.
1858. ‡Matthews, F. C. Mandre Works, Driffield, Yorkshire.
1860. §Matthews, Rev. Richard Brown. Shalford Vicarage, near Guildford.
1863. ‡Maughan, Rev. W. Benwell Parsonage, Newcastle-on-Tyne.
1855. ‡Maule, Rev. Thomas, M.A. Partick, near Glasgow.
1865. *MAW, GEORGE, F.L.S., F.G.S., F.S.A. Benthall Hall, Broseley, Shropshire.
1864. *Maxwell, Francis. Dunragit, Wigtownshire.
*MAXWELL, JAMES CLERK, M.A., LL.D., F.R.S.L. & E., Professor of Experimental Physics in the University of Cambridge. Glenlair, Dalbeattie, N.B.; and 11 Scroope-terrace, Cambridge.
*Maxwell, Robert Perceval. Groomsport House, Belfast.
1865. *May, Walter. Elmley Lodge, Harborne, Birmingham.
1868. ‡Mayall, J. E., F.C.S. Stork's-nest, Lancing, Sussex.
1863. §Mease, George D. Bylton Villa, South Shields.
1863. ‡Mease, Solomon. Cleveland House, North Shields.
‡Meath, Samuel Butcher, D.D., Lord Bishop of. Ardbraccan, Co. Meath.
1871. ‡Meikie, James, F.S.S. 6 St. Andrew's-square, Edinburgh.
1867. ‡MELDRUM, CHARLES. Mauritius.
1866. ‡Mello, Rev. J. M. St. Thomas's Rectory, Brampton, Chesterfield.
1854. ‡Melly, Charles Pierre. 11 Rumford-street, Liverpool.
1847. ‡Melville, Professor Alexander Gordon, M.D. Queen's College, Galway.
1863. ‡Melvin, Alexander. 42 Buccleuch-place, Edinburgh.
1862. §MENNELL, HENRY J. St. Dunstan's-buildings, Great Tower-street, London, E.C.
1868. §MERRIFIELD, CHARLES W., F.R.S. 20 Pembroke-gardens, Kensington, London, W.
1872. ‡Merryweather, Richard M. Clapham House, Clapham Common, London, S.W.

Year of
Election.

1871. ‡Merson, John. Northumberland County Asylum, Morpeth.
1872. *Messent, John. 429 Strand, London, W.C.
1863. ‡Messent, P. T. 4 Northumberland-terrace, Tynemouth.
1869. §MIALL, LOUIS C. Philosophical Hall, Leeds
1847. *Michell, Rev. Richard, D.D., Principal of Magdalen Hall, Oxford.
1865. ‡Michie, Alexander. 26 Austin Friars, London, E.C.
1865. ‡Middlemore, William. Edgbaston, Birmingham.
1866. ‡Midgley, John. Colne, Lancashire.
1867. ‡Midgley, Robert. Colne, Lancashire.
1859. ‡Millar, John. Lisburn, Ireland.
1863. §Millar, John, M.D., F.L.S., F.G.S. Bethnal House, Cambridge-road, London, E.
Millar, Thomas, M.A., LL.D., F.R.S.E. Perth.
1875. §Miller, George. Brentry, near Bristol.
1865. ‡Miller, Rev. Canon J. C., D.D. The Vicarage, Greenwich, London, S.E.
1861. *Miller, Robert. Broomfield House, Reddish, near Manchester.
MILLER, WILLIAM HALLOWS, M.A., LL.D., F.R.S., F.G.S., Professor of Mineralogy in the University of Cambridge. 7 Scroope-terrace, Cambridge.
1868. *Milligan, Joseph, F.L.S., F.G.S., F.R.A.S., F.R.G.S. 6 Craven-street, Strand, London, W.C.
1842. Milligan, Robert. Acacia in Rawdon, Leeds.
1868. §MILLS, EDMUND J., D.Sc., F.R.S., F.C.S., Young Professor of Technical Chemistry in Anderson's University, Glasgow. 234 East George-street, Glasgow.
*Mills, John Robert. 11 Bootham, York.
Milne, Admiral Sir Alexander, G.C.B., F.R.S.E. 65 Rutland-gate, London, S.W.
1867. ‡Milne, James. Murie House, Errol, by Dundee.
1867. *MILNE-HOME, DAVID, M.A., F.R.S.E., F.G.S. 10 York-place, Edinburgh.
1864. *MILTON, The Right Hon. Lord, F.R.G.S. 17 Grosvenor-street, London, W.; and Wentworth, Yorkshire.
1865. ‡Minton, Samuel, F.G.S. Oakham House, near Dudley.
1855. ‡Mirrlees, James Buchanan. 45 Scotland-street, Glasgow.
1859. ‡Mitchell, Alexander, M.D. Old Rain, Aberdeen.
1863. ‡Mitchell, C. Walker. Newcastle-on-Tyne.
1873. ‡Mitchell, Henry. Parkfield House, Bradford, Yorkshire.
1870. §Mitchell, John. York House, Clitheroe, Lancashire.
1868. §Mitchell, John, jun. Pole Park House, Dundee.
1862. **Mitchell, William Stephen, LL.B., F.L.S., F.G.S. Caius College, Cambridge.*
1855. *Moffat, John, C.E. Ardrossan, Scotland.
1854. §MOFFAT, THOMAS, M.D., F.G.S., F.R.A.S., F.M.S. Hawarden, Chester.
1864. ‡Mogg, John Rees. High Littleton House, near Bristol.
1866. §MOGGRIDGE, MATTHEW, F.G.S. 8 Bina-gardens, South Kensington, London, S.W.
1855. §Moir, James. 174 Gallogate, Glasgow.
1861. ‡Molesworth, Rev. W. N., M.A. Spotland, Rochdale.
Mollan, John, M.D. 8 Fitzwilliam-square North, Dublin.
1852. ‡Molony, William, LL.D. Carrickfergus.
1865. §MOLYNEUX, WILLIAM, F.G.S. Branston Cottage, Burton-upon-Trent.
1860. ‡Monk, Rev. William, M.A., F.R.A.S. Wymington Rectory, Higham Ferrers, Northamptonshire.

Year of Election

1853. ‡Monroe, Henry, M.D. 10 North-street, Sculcoates, Hull.
1875. §Montgomerie, Major Thomas George, R.E., F.R.S., F.R.G.S., Deputy Superintendent of the Great Trigonometrical Survey of India. Athenæum Club, London, S.W.
1872. §Montgomery, R. Mortimer. 3 Porchester-place, Edgeware-road, London, W.
1872. ‡Moon, W., LL.D. 104 Queen's-road, Brighton.
1859. ‡MOORE, CHARLES, F.G.S. 6 Cambridge-terrace, Bath.
1874. §Moore, David, F.L.S. Glasnevin, Dublin.
1857. ‡Moore, Rev. John, D.D. Clontarf, Dublin.
Moore, John. 2 Meridian-place, Clifton, Bristol.
*MOORE, JOHN CARRICK, M.A., F.R.S., F.G.S. 113 Eaton-square, London, S.W.; and Corswall, Wigtonshire.
1866. *MOORE, THOMAS, F.L.S. Botanic Gardens, Chelsea, London, S.W.
1854. ‡MOORE, THOMAS JOHN, Cor. M.Z.S. Free Public Museum, Liverpool.
1857. *Moore, Rev. William Prior. The Royal School, Cavan, Ireland.
1871. ‡MORE, ALEXANDER, F.L.S., M.R.I.A. 3 Botanic View, Glasnevin, Dublin.
1873. §Morgan, Edward Delmar. 15 Rowland-gardens, London, W.
1868. ‡Morgan, Thomas H. Oakhurst, Hastings.
1833. Morgan, William, D.C.L. Oxon. Uckfield, Sussex.
1867. ‡Morison, William R. Dundee.
1863. ‡MORLEY, SAMUEL, M.P. 18 Wood-street, Cheapside, London, E.C.
1865. *Morrieson, Colonel Robert. Oriental Club, Hanover-square, London, W.
*Morris, Rev. Francis Orpen, B.A. Nunburnholme Rectory, Hayton, York.
Morris, Samuel, M.R.D.S. Fortview, Clontarf, near Dublin.
1861. ‡*Morris, William.*
1874. §Morrison, G. J., C.E. 5 Victoria-street, Westminster, S.W.
1871. *Morrison, James Darsie. 27 Grange-road, Edinburgh.
1863. ‡*Morrow, R. J. Bentick-villas, Newcastle-on-Tyne.*
1865. §Mortimer, J. R. St. John's-villas, Driffield.
1869. ‡Mortimer, William. Bedford-circus, Exeter.
1857. §MORTON, GEORGE H., F.G.S. 21 West Derby-street, Liverpool.
1858. *MORTON, HENRY JOSEPH. Garforth House, West Garforth, near Leeds.
1871. ‡Morton, Hugh. Belvedere House, Trinity, Edinburgh.
1868. ‡Moseley, H. N. Olveston, Bristol.
1857. ‡Moses, Marcus. 4 Westmoreland-street, Dublin.
Mosley, Sir Oswald, Bart., D.C.L. Rolleston Hall, Burton-upon-Trent, Staffordshire.
Moss, John. Otterspool, near Liverpool.
1870. ‡Moss, John Miles, M.A. 2 Esplanade, Waterloo, Liverpool.
1873. *Mosse, George S. Clarendon House, Stanford-road, Kensington, London, W.
1864. *Mosse, J. R. Public Works' Department, Ceylon. (Care of Messrs. H. S. King & Co., 65 Cornhill, London, E.C.)
1873. §Mossman, William. Woodhall, Calverley, Leeds.
1869. §MOTT, ALBERT J. Adsett Court, Westbury-on-Severn.
1865. §Mott, Charles Grey. The Park, Birkenhead.
1866. §Mott, Frederick T., F.R.G.S. 1 De Montfort-street, Leicester.
1872. §Mott, Miss Minnie. 1 De Montfort-street, Leicester.
1862. *MOUAT, FREDERICK JOHN, M.D., Local Government Inspector. 12 Durham-villas, Campden-hill, London, W.
1856. ‡Mould, Rev. J. G., B.D. Fulmodeston Rectory, Dereham, Norfolk.

Year of Election.

1863. ‡Mounsey, Edward. Sunderland.
Mounsey, John. Sunderland.
1861. *Mountcastle, William Robert. Ellenbrook, near Manchester.
Mowbray, James. Combus, Clackmannan, Scotland.
1850. ‡Mowbray, John T. 15 Albany-street, Edinburgh.
1874. §Muir, M. M. Pattison. Owens College, Manchester.
1871. ‡*Muir, W. Hamilton.*
1872. †Muirhead, Alexander, D.Sc., F.C.S. 159 Camden-road, London, N.
1871. *Muirhead, Henry, M.D. Bushy-hill, Cambuslang, Lanarkshire.
1857. ‡*Mullins, M. Bernard, M.A., C.E.*
Munby, Arthur Joseph. 6 Fig-tree-court, Temple, London, E.C.
1866. ‡MUNDELLA, A. J., M.P., F.R.G.S. The Park, Nottingham.
1864. *MUNRO, Major-General WILLIAM, C.B., F.L.S. United Service Club, Pall Mall, London, S.W.; and Mapperton Lodge, Farnborough, Hants.
1872. *Munster, H. Sillwood Lodge, Brighton.
1872. *Munster, William Felix. 41 Brompton-square, London, W.
1864. §MURCH, JEROM. Cranwells, Bath.
*Murchison, John Henry. Surbiton-hill, Kingston, S.W.
1864. *Murchison, K. R. Ashurst Lodge, East Grinstead.
1855. ‡Murdock, James B. Hamilton-place, Langside, Glasgow.
1852. ‡Murney, Henry, M.D. 10 Chichester-street, Belfast.
1852. ‡Murphy, Joseph John. Old Forge, Dunmurry, Co. Antrim.
1869. §Murray, Adam. 4 Westbourne-crescent, Hyde Park, London, W.
1850. ‡MURRAY, ANDREW, F.L.S. 67 Bedford-gardens, Kensington, London, W.
1871. ‡Murray, Dr. Ivor, F.R.S.E. The Knowle, Brenchley, Staplehurst, Kent.
Murray, John, F.G.S., F.R.G.S. 50 Albemarle-street, London, W.; and Newsted, Wimbledon, Surrey.
1871. §Murray, John. 3 Clarendon-crescent, Edinburgh.
1859. ‡Murray, John, M.D. Forres, Scotland.
*Murray, John, C.E. Downlands, Sutton, Surrey.
‡Murray, Rev. John. Morton, near Thornhill, Dumfriesshire.
1872. ‡Murray, J. Jardine. 99 Montpellier-road, Brighton.
1863. ‡Murray, William. 34 Clayton-street, Newcastle-on-Tyne.
1859. *Murton, James. Highfield, Silverdale, Carnforth, Lancaster.
Musgrave, The Venerable Charles, D.D., Archdeacon of Craven, Halifax.
1874. §Musgrave, James, J.P. Drumglass House, Belfast.
1861. ‡Musgrove, John, jun. Bolton.
1870. *Muspratt, Edward Knowles. Seaforth Hall, near Liverpool.
1865. ‡Myers, Rev. E., F.G.S. 3 Waterloo-road, Wolverhampton.
1859. §MYLNE, ROBERT WILLIAM, F.R.S., F.G.S., F.S.A. 21 Whitehall-place, London, S.W.

1850. ‡Nachot, H. W., Ph.D. 73 Queen-street, Edinburgh.
1842. Nadin, Joseph. Manchester.
1855. *NAPIER, JAMES R., F.R.S. 22 Blythwood-square, Glasgow.
*Napier, Captain Johnstone, C.E. Laverstock House, Salisbury.
1839. *NAPIER, The Right Hon. Sir JOSEPH, Bart. 4 Merrion-square South, Dublin.
1855. ‡Napier, Robert. West Shandon, Gareloch, Glasgow.
Napper, James William L. Loughcrew, Oldcastle., Co. Meath.
1872. §Nares, Captain G. S., R.N., F.R.S. Stoneham House, Christchurch-road, Winchester.
1866. †Nash, Davyd W., F.S.A., F.L.S. 10 Imperial-square, Cheltenham.

Year of Election.

1850. *NASMYTH, JAMES. Penshurst, Tunbridge.
1864. ‡Natal, William Colenso, Lord Bishop of. Natal.
1860. ‡Neate, Charles, M.A. Oriel College, Oxford.
1867. §NEAVES, The Right Hon. Lord. 7 Charlotte-square, Edinburgh.
1873. ‡Neill, Alexander Renton. Fieldhead House, Bradford, Yorkshire.
1873. ‡Neill, Archibald. Fieldhead House, Bradford, Yorkshire.
1855. ‡Neilson, Walter. 172 West George-street, Glasgow.
1865. ‡Neilson, W. Montgomerie. Glasgow.
Ness, John. Helmsley, near York.
1868. ‡Nevill, Rev. H. R. The Close, Norwich.
1866. *Nevill, Rev. Samuel Tarratt, D.D., F.L.S., Bishop of Dunedin, New Zealand.
1857. ‡Neville, John, C.E., M.R.I.A. Roden-place, Dundalk, Ireland.
1852. ‡Neville, Parke, C.E. Town Hall, Dublin.
1869. ‡Nevins, John Birkbeck, M.D. 3 Abercromby-square, Liverpool.
1842. New, Herbert. Evesham, Worcestershire.
Newall, Henry. Hare-hill, Littleborough, Lancashire.
*Newall, Robert Stirling, F.R.S., F.R.A.S. Ferndene, Gateshead-upon-Tyne.
1866. *Newdigate, Albert L. 2 The Pavement, Clapham Common, London, S.W.
1842. *NEWMAN, Professor FRANCIS WILLIAM. 15 Arundel-crescent, Weston-super-Mare.
1863. *NEWMARCH, WILLIAM, F.R.S. Beech Holme, Clapham Common, London, S.W.
1866. **Newmarch, William Thomas.*
1860. *NEWTON, ALFRED, M.A., F.R.S., F.L.S., Professor of Zoology and Comparative Anatomy in the University of Cambridge Magdalen College, Cambridge.
1872. ‡Newton, Rev. J. 125 Eastern-road, Brighton.
1865. ‡Newton, Thomas Henry Goodwin. Clopton House, near Stratford-on-Avon.
1867. ‡Nicholl, Dean of Guild. Dundee.
1875. §Nicholls, J. F. City Library, Bristol.
1874. §Nicholls, N. F. King's-square, Bridgewater, Somerset.
1866. ‡NICHOLSON, Sir CHARLES, Bart., D.C.L., LL.D., M.D., F.G.S., F.R.G.S. 26 Devonshire-place, Portland-place, London, W.
1838. *Nicholson, Cornelius, F.G.S., F.S.A. Wellfield, Muswell-hill, London, N.
1861. *Nicholson, Edward. 88 Mosley-street, Manchester.
1871. §Nicholson, E. Chambers. Herne-hill, London, S.E.
1867. ‡NICHOLSON, HENRY ALLEYNE, M.D., D.Sc., F.G.S., Professor of Natural History in the University of St. Andrews, N.B.
1850. ‡NICOL, JAMES, F.R.S.E., F.G.S., Professor of Natural History in Marischal College, Aberdeen.
1867. ‡Nimmo, Dr. Matthew, L.R.C.S.E. Nethergate, Dundee.
Niven, Ninian. Clonturk Lodge, Drumcondra, Dublin.
‡Nixon, Randal, C. J., M.A. Green Island, Belfast.
1864. ‡NOAD, HENRY M., Ph.D., F.R.S., F.C.S. 72 Hereford-road, Bayswater, London, W.
1863. *NOBLE, Captain, F.R.S. Elswick Works, Newcastle-on-Tyne.
1870. ‡Nolan, Joseph. 14 Hume-street, Dublin.
1860. *Nolloth, Rear-Admiral Matthew S., R.N., F.R.G.S. United Service Club, S.W.; and 13 North-terrace, Camberwell, London, S.E.
1859. ‡Norfolk, Richard. Messrs. W. Rutherford and Co., 14 Canada Dock, Liverpool.
1868. ‡Norgate, William. Newmarket-road, Norwich.

Year of Election.

1863. §Norman, Rev. Alfred Merle, M.A. Burnmoor Rectory, Fence House, Co. Durham.
Norreys, Sir Denham Jephson, Bart. Mallow Castle, Co. Cork.
1865. ‡Norris, Richard, M.D. 2 Walsall-road, Birchfield, Birmingham.
1872. §Norris, Thomas George. Gorphwysfa, Llanrwst, North Wales.
1866. ‡North, Thomas. Cinder-hill, Nottingham.
Northampton, The Right Hon. Charles Douglas, Marquis of. Castle Ashby, Northamptonshire; and 145 Piccadilly, London, W.
1869. ‡Northcote, The Right Hon. Sir Stafford H., Bart., C.B., M.P., F.R.S. Pynes, Exeter; and 86 Harley-street, London, W.
*Northwick, The Right Hon. Lord, M.A. 7 Park-street, Grosvenor-square, London, W.
1868. ‡Norwich, The Hon. and Right Rev. J. T. Pelham, D.D., Lord Bishop of. Norwich.
1861. ‡Noton, Thomas. Priory House, Oldham.
Nowell, John. Farnley Wood, near Huddersfield.

O'Brien, Baron Lucius. Dromoland, Newmarket-on-Fergus, Ireland.
O'Callaghan, George. Tallas, Co. Clare.
Odgers, Rev. William James. Savile House, Weston-road, Bath.
1858. *Odling, William, M.B., F.R.S., F.C.S., Waynflete Professor of Chemistry in the University of Oxford. The Museum, Oxford.
1857. ‡O'Donnavan, William John. Portarlington, Ireland.
1870. ‡O'Donnell, J. O., M.D. 34 Rodney-street, Liverpool.
1866. ‡Ogden, James. Woodhouse, Loughborough.
1859. ‡Ogilvie, C. W. Norman. Baldovan House, Dundee.
*Ogilvie, George, M.D., Professor of the Institutes of Medicine in Marischal College, Aberdeen. 29 Union-place, Aberdeen.
1874. §Ogilvie, Thomas Robertson. 19 Brisbane-street, Greenock, N.B.
1863. ‡Ogilvy, G. R. Inverquharity, N.B.
1863. ‡Ogilvy, Sir John, Bart. Inverquharity, N.B.
*Ogle, William, M.D., M.A. The Elms, Derby.
1859. ‡Ogston, Francis, M.D. 18 Adelphi-court, Aberdeen.
1837. ‡O'Hagan, John. 22 Upper Fitzwilliam-street, Dublin.
1874. §O'Hagan, The Right Hon. Lord. Dublin.
1862. ‡O'Kelly, Joseph, M.A. 51 Stephen's-green, Dublin.
1857. ‡O'Kelly, Matthias J. Dalkey, Ireland.
1853. §Oldham, James, C.E. Cottingham, near Hull.
1857. *Oldham, Thomas, M.A., LL.D., F.R.S., F.G.S., M.R.I.A., Director of the Geological Survey of India. 1 Hastings-street, Calcutta.
1860. ‡O'Leary, Professor Purcell, M.A. Queenstown.
1863. ‡Oliver, Daniel, F.R.S., Professor of Botany in University College, London. Royal Gardens, Kew, W.
1874. ‡O'Meara, Rev. Eugene. Newcastle Rectory, Hazlehatch, Ireland.
*Ommanney, Vice-Admiral Erasmus, C.B., F.R.S., F.R.A.S., F.R.G.S. 6 Talbot-square, Hyde Park, London, W.; and United Service Club, Pall Mall, London, S.W.
1872. ‡Onslow, D. Robert. New University Club, St. James's, London, S.W.
1867. ‡Orchar, James G. 9 William-street, Forebank, Dundee.
1842. Ormerod, George Wareing, M.A., F.G.S. Brookbank, Teignmouth.
1861. ‡Ormerod, Henry Mere. Clarence-street, Manchester; and 11 Woodland-terrace, Cheetham-hill, Manchester.
1858. ‡Ormerod, T. T. Brighouse, near Halifax.
1835. Orpen, John H., LL.D., M.R.I.A. 58 Stephen's-green, Dublin.
1873. ‡Osborn, George. 47 Kingcross-street, Halifax.

Year of Election.
1865. ‡Osborne, E. C. Carpenter-road, Edgbaston, Birmingham.
*OSLER, A. FOLLETT, F.R.S. South Bank, Edgbaston, Birmingham.
1865. *Osler, Henry F. 50 Carpenter-road, Edgbaston, Birmingham.
1869. *Osler, Sidney F. South Bank, Edgbaston, Birmingham.
1854. ‡Outram, Thomas. Greetland, near Halifax.
OVERSTONE, SAMUEL JONES LLOYD, Lord, F.G.S. 2 Carlton-gardens, London, S.W.; and Wickham Park, Bromley.
1870. ‡Owen, Harold. The Brook Villa, Liverpool.
1857. ‡Owen, James H. Park House, Sandymount, Co. Dublin.
OWEN, RICHARD, C.B., M.D., D.C.L., LL.D., F.R.S., F.L.S., F.G.S., Hon. M.R.S.E., Director of the Natural-History Department, British Museum. Sheen Lodge, Mortlake, Surrey, S.W.
1863. *Ower, Charles, C.E. 11 Craigie-terrace, Dundee.

1859. ‡PAGE, DAVID, LL.D., F.R.S.E., F.G.S. College of Physical Science, Newcastle-upon-Tyne.
1863. ‡Paget, Charles. Ruddington Grange, near Nottingham.
1872. *Paget, Joseph. Stuffynwood Hall, Mansfield, Nottingham.
1875. §Paine, William Henry, M.D., F.G.S. Stroud, Gloucestershire.
1870. *Palgrave, R. H. Inglis. 11 Britannia-terrace, Great Yarmouth.
1873. ‡Palmer, George. The Acacias, Reading, Berks.
1866. §Palmer, H. 76 Goldsmith-street, Nottingham.
1866. §Palmer, William. Iron Foundry, Canal-street, Nottingham.
1872. *Palmer, W. R. Phœnix Lodge, Brixton, London, S.W.
Palmes, Rev. William Lindsay, M.A. The Vicarage, Hornsea, Hull.
1857. *Parker, Alexander, M.R.I.A. 59 William-street, Dublin.
1863. ‡Parker, Henry. Low Elswick, Newcastle-on-Tyne.
1863. ‡Parker, Rev. Henry. Idlerton Rectory, Low Elswick, Newcastle-on-Tyne.
1874. ‡Parker, Henry R., LL.D. Methodist College, Belfast.
Parker, Joseph, F.G.S. Upton Chaney, Bitton, near Bristol.
Parker, Richard. Dunscombe, Cork.
1865. *Parker, Walter Mantel. High-street, Alton, Hants.
Parker, Rev. William. Saham, Norfolk.
1853. ‡Parker, William. Thornton-le-Moor, Lincolnshire.
1865. *Parkes, Samuel Hickling. King's Norton, near Birmingham.
1864 §PARKES, WILLIAM. 23 Abingdon-street, Westminster, S.W.
1859. ‡Parkinson, Robert, Ph.D. West View, Toller-lane, Bradford, Yorkshire.
1862. *Parnell, John, M.A. Hadham House, Upper Clapton, London, E.
Parnell, Richard, M.D., F.R.S.E. Gattonside Villa, Melrose, N.B.
1865. *Parsons, Charles Thomas. 8 Portland-road, Edgbaston, Birmingham.
1875. §Pass, Alfred C. 16 Redland Park, Clifton, Bristol.
1855. ‡Paterson, William. 100 Brunswick-street, Glasgow.
1861. ‡Patterson, Andrew. Deaf and Dumb School, Old Trafford, Manchester.
1871. *Patterson, A. H. Craigdarragh, Belfast.
1863. ‡Patterson, H. L. Scott's House, near Newcastle-on-Tyne.
1867. ‡Patterson, James. Kinnettles, Dundee.
1871. ‡*Patterson, John.*
1874. ‡Patterson, W. H., M.R.I.A. 26 High-street, Belfast,
1863. ‡Pattinson, John. 75 The Side, Newcastle-on-Tyne.
1863. ‡Pattinson, William. Felling, near Newcastle-on-Tyne.
1867. §Pattison, Samuel R., F.G.S. 50 Lombard-street, London, E.C.
1864. ‡Pattison, Dr. T. H. London-street, Edinburgh.
1863. ‡PAUL, BENJAMIN H., Ph.D. 1 Victoria-street, Westminster, S.W.
1863. ‡PAVY, FREDERICK WILLIAM, M.D., F.R.S., Lecturer on Physiology and Comparative Anatomy and Zoology at Guy's Hospital. 35 Grosvenor-street, London, W.

Year of
Election.

1864. ‡Payne, Edward Turner. 3 Sydney-place, Bath.

1851. ‡Payne, Joseph. 4 Kildare-gardens, Bayswater, London, W.

1866. ‡Payne, Dr. Joseph F. 4 Kildare-gardens, Bayswater, London, W.

1847. ‡PEACH, CHARLES W., Pres. R.P.S. Edin., A.L.S. 30 Haddington-place, Leith-walk, Edinburgh.

1863. §Peacock, Richard Atkinson, C.E., F.G.S. 2 Moselle-villas, St. Peter's-road, Margate.

1875. §Peacock, Thomas Francis. 12 South-square, Gray's Inn, London, W.C.

*Pearsall, Thomas John, F.C.S. Birkbeck Literary and Scientific Institution, Southampton-buildings, Chancery-lane, London, W.C.

1875. §Pearson, H. W. Tramore Villa, Nugent Hill, Cotham, Bristol.

1872. *Pearson, Joseph. 54 Welbeck-terrace, Mansfield-road, Nottingham.

1870. ‡Pearson, Rev. Samuel. 48 Prince's-road, Liverpool.

1863. §Pease, H. F. Brinkburn, Darlington.

1863. *Pease, Joseph W., M.P. Hutton Hall, near Guisborough.

1863. ‡Pease, J. W. Newcastle-on-Tyne.

1858. *Pease, Thomas, F.G.S. Cote Bank, Westbury-on-Trym, near Bristol.

Peckitt, Henry. Carlton Husthwaite, Thirsk, Yorkshire.

1855. *Peckover, Alexander, F.L.S., F.R.G.S. Harecroft House, Wisbeach, Cambridgeshire.

*Peckover, Algernon, F.L.S. Sibaldsholme, Wisbeach, Cambridgeshire.

*Peckover, William, F.S.A. Wisbeach, Cambridgeshire.

*Peel, George. Soho Iron Works, Manchester.

1873. §Peel, Thomas. Hampton-place, Horton, Yorkshire.

1861. *Peile, George, jun. Shotley Bridge, Co. Durham.

1861. *Peiser, John. Barnfield House, 491 Oxford-street, Manchester.

1865. ‡Pemberton, Oliver. 18 Temple-row, Birmingham.

1861. *Pender, John, M.P. 18 Arlington-street, London, S.W.

1868. ‡Pendergast, Thomas. Lancefield, Cheltenham.

1856. §PENGELLY, WILLIAM, F.R.S., F.G.S. Lamorna, Torquay.

1875. §Percival, Rev. J., M.A., LL.D. The College, Clifton, Bristol.

1845. ‡PERCY, JOHN, M.D., F.R.S., F.G.S., Professor of Metallurgy in the Government School of Mines, Museum of Practical Geology, Jermyn-street, S.W.; and 1 Gloucester-crescent, Hyde Park, London, W.

*Perigal, Frederick. Thatched House Club, St. James's-street, London, S.W.

1868. *PERKIN, WILLIAM HENRY, F.R.S., F.C.S. The Chestnuts, Sudbury, Harrow.

1861. ‡Perkins, Rev. George. St. James's View, Dickenson-road, Rusholme, near Manchester.

Perkins, Rev. R. B., D.C.L. Wotton-under-Edge, Gloucestershire.

1864. *Perkins, V. R. The Brands, Wotton-under-Edge, Gloucestershire.

1861. ‡Perring, John Shae. 104 King-street, Manchester.

Perry, The Right Rev. Charles, M.A., D.D., Bishop of Melbourne, Australia.

1874. ‡Perry, John. 5 Falls-road, Belfast.

*Perry, Rev. S. G. F., M.A. Tottington Vicarage, near Bury.

1870. *PERRY, Rev. S. J., F.R.S., F.R.A.S., F.M.S. Stonyhurst College Observatory, Whalley, Blackburn.

1861. *Petrie, John. South-street, Rochdale.

Peyton, Abel. Oakhurst, Edgbaston, Birmingham.

1871. *Peyton, John E. H., F.R.A.S., F.G.S. 108 Marina, St. Leonard's-on-Sea.

1867. ‡PHAYRE, Major-General Sir ARTHUR, K.C.S.I. East India United Service Club, St. James's-square, London, S.W.

Year of
Election.

1863. *PHENÉ, JOHN SAMUEL, F.S.A., F.G.S., F.R.G.S. 5 Carlton-terrace, Oakley-street, London, S.W.
1870. §Philip, T. D. 51 South Castle-street, Liverpool.
1853. *Philips, Rev. Edward. Hollington, Uttoxeter, Staffordshire.
1853. *Philips, Herbert. 35 Church-street, Manchester.
*Philips, Mark. Welcombe, Stratford-on-Avon.
Philips, Robert N. The Park, Manchester.
1863. ‡Philipson, Dr. 1 Saville-row, Newcastle-on-Tyne.
1859. *PHILLIPS, Major-General Sir B. TRAVELL. United Service Club, Pall Mall, London, S.W.
1862. ‡Phillips, Rev. George, D.D. Queen's College, Cambridge.
1870. ‡PHILLIPS, J. ARTHUR. Cressington Park, Aigburth, Liverpool.
1868. ‡Phipson, R. M., F.S.A. Surrey-street, Norwich.
1868. ‡PHIPSON, T. L., Ph.D. 4 The Cedars, Putney, Surrey, S.W.
1864. ‡Pickering, William. Oak View, Clevedon.
1861. ‡Pickstone, William. Radcliff Bridge, near Manchester.
1870. §Picton, J. Allanson, F.S.A. Sandyknowe, Wavertree, Liverpool.
1870. ‡Pigot, Rev. E. V. Malpas, Cheshire.
1871. ‡Pigot, Thomas F. Royal College of Science, Dublin.
*Pike, Ebenezer. Besborough, Cork.
1865. ‡PIKE, L. OWEN. 25 Carlton-villas, Maida-vale, London, W.
1873. §Pike, W. H. 4 The Grove, Highgate, London, N.
1857. ‡Pilkington, Henry M., M.A., Q.C. 45 Upper Mount-street, Dublin.
1863. *PIM, Captain BEDFORD C. T., R.N., M.P., F.R.G.S. Leaside, Kingswood-road, Upper Norwood, London, S.E.
Pim, George, M.R.I.A. Brennan's Town, Cabinteely, Dublin.
Pim, Jonathan. Harold's Cross, Dublin.
Pim, William H. Monkstown, Dublin.
1861. ‡*Pincoffs, Simon.*
1868. ‡Pinder, T. R. St. Andrews, Norwich.
1859. ‡Pirrie, William, M.D., LL.D. 238 Union-street West, Aberdeen.
1866. ‡Pitcairn, David. Dudhope House, Dundee.
1875. §Pitman, John. Redcliff Hill, Bristol.
1864. ‡Pitt, R. 5 Widcomb-terrace, Bath.
1869. §PLANT, JAMES, F.G.S. 40 West-terrace, West-street, Leicester.
1865. ‡Plant, Thomas L. Camp-hill, and 33 Union-street, Birmingham.
1867. ‡PLAYFAIR, Lieut.-Colonel, H.M. Consul, Algeria. (Messrs. King & Co., Pall Mall, London, S.W.)
1842. PLAYFAIR, The Right Hon. LYON, C.B., Ph.D., LL.D., M.P., F.R.S.L. & E., F.C.S. 68 Onslow-gardens, South Kensington, London, S.W.
1857. ‡Plunkett, Thomas. Ballybrophy House, Borris-in-Ossory, Ireland.
1861. *POCHIN, HENRY DAVIS, F.C.S. Broughton Old Hall, Manchester.
1846. ‡POLE, WILLIAM, Mus. Doc., F.R.S., M.I.C.E. Athenæum Club, Pall Mall, London, S.W.
*Pollexfen, Rev. John Hutton, M.A. Middleton Tyas Vicarage, Richmond, Yorkshire.
Pollock, A. 52 Upper Sackville-street, Dublin.
1862. *Polwhele, Thomas Roxburgh, M.A., F.G.S. Polwhele, Truro, Cornwall.
1854. ‡Poole, Braithwaite. Birkenhead.
1868. ‡Pooley, Thomas A., B.Sc. South Side, Clapham Common, London, S.W.
1868. ‡Portal, Wyndham S. Malsanger, Basingstoke.
*PORTER, HENRY J. KER, M.R.I.A. Hanover Square Club, Hanover-square, London, W.
1874. ‡Porter, Rev. J. Leslie, D.D., LL.D. College Park, Belfast.
1866. §Porter, Robert. Beeston, Nottingham.

Year of Election.

Porter, Rev. T. H., D.D. Desertcreat, Co. Armagh.
1863. ‡Potter, D. M. Cramlington, near Newcastle-on-Tyne.
*POTTER, EDMUND, F.R.S. Camfield-place, Hatfield, Herts.
1842. Potter, Thomas. George-street, Manchester.
1863. ‡Potts, James. 26 Sandhill, Newcastle-on-Tyne.
1857. *POUNDEN, Captain LONSDALE, F.R.G.S. Junior United Service Club, St. James's-square, London, S.W.; and Brownswood House, Enniscorthy, Co. Wexford.
1873. *Powell, Francis S. Horton Old Hall, Yorkshire; and 1 Cambridge-square, London, W.
1875. §Powell, William Augustus Frederick. Norland House, Clifton, Bristol.
1857. ‡Power, Sir James, Bart. Edermine, Enniscorthy, Ireland.
1867. ‡Powrie, James. Reswallie, Forfar.
1855. *Poynter, John E. Clyde Neuck, Uddingstone, Hamilton, Scotland.
1864. ‡*Prangley, Arthur.*
1869. *Preece, William Henry. Gothic Lodge, Wimbledon Common, London, S.W.
1864. *Prentice, Manning. Violet-hill, Stowmarket, Suffolk.
Prest, The Venerable Archdeacon Edward. The College, Durham.
*PRESTWICH, JOSEPH, F.R.S., F.G.S., F.C.S., Professor of Geology in the University of Oxford. 34 Broad-street, Oxford; and Shoreham, near Sevenoaks.
1871. ‡Price, Astley Paston. 47 Lincoln's-Inn-Fields, London, W.C.
1856. *PRICE, Rev. BARTHOLOMEW, M.A., F.R.S., F.R.A.S., Sedleian Professor of Natural Philosophy in the University of Oxford 11 St. Giles's-street, Oxford.
1872. ‡Price, David S., Ph.D. 26 Great George-street, Westminster, S.W.
Price, J. T. Neath Abbey, Glamorganshire.
1875. *Price, Rees. 54 Loftus-road, Shepherd's Bush, London, W.
1870. §Price, Captain W. E., M.P., F.G.S. Tibberton Court, Gloucester.
1875. *Price, William Philip. Tibberton Court, Gloucester.
1865. *Prichard, Thomas, M.D. Abington Abbey, Northampton.
1865. ‡*Prideaux, J. Symes. 209 Piccadilly, London.*
1875. §Prince, Thomas. 6 Marlborough-road, Bradford, Yorkshire.
1864. *Prior, R. C. A., M.D. 48 York-terrace, Regent's Park, London, N.W.
1835. *Pritchard, Andrew, F.R.S.E. 87 St. Paul's-road, Canonbury, London, N.
1846. *PRITCHARD, Rev. CHARLES, M.A., F.R.S., F.G.S., F.R.A.S., Professor of Astronomy in the University of Oxford. 8 Keble-terrace, Oxford.
1872. ‡Pritchard, Rev. W. Gee. Brignal Rectory, Barnard Castle, Co. Durham.
1871. ‡*Procter, James. Morton House, Clifton, Bristol.*
1863. ‡Procter, R. S. Summerhill-terrace, Newcastle-on-Tyne.
Proctor, Thomas. Elmsdale House, Clifton Down, Bristol.
Proctor, William. Elmhurst, Higher Erith-road, Torquay.
1858. §Proctor, William, M.D., F.C.S. 24 Petergate, York.
1863. *Prosser, Thomas. West Boldon, Newcastle-on-Tyne.
1863. ‡Proud, Joseph. South Hetton, Newcastle-on-Tyne.
1865. ‡Prowse, Albert P. Whitchurch Villa, Mannamead, Plymouth.
1872. *Pryor, M. Robert. Weston Manor, Stevenage, Herts.
1871. *Puckle, Thomas John. Woodcote-grove, Carshalton, Surrey.
1864. ‡Pugh, John. Aberdovey, Shrewsbury.
1873. ‡Pullan, Lawrence. Bridge of Allan, N.B.
1867. ‡Pullar, John. 4 Leonard Bank, Perth.
1867. *Pullar, Robert. 6 Leonard Bank, Perth.
1842. *Pumphrey, Charles. 33 Frederick-road, Edgbaston, Birmingham.

Year of
Election.

Punnett, Rev. John, M.A., F.C.P.S. St. Earth, Cornwall.
1869. ‡*Purchas, Rev. W. H.*
1852. ‡Purdon, Thomas Henry, M.D. Belfast.
1860. ‡PURDY, FREDERICK, F.S.S., Principal of the Statistical Department of the Poor Law Board, Whitehall, London. Victoria-road, Kensington, London, W.
1874. ‡Purser, Frederick, M.A. Rathmines, Dublin.
1866. ‡Purser, Professor John, M.A., M.R.I.A. Queen's College, Belfast.
1860. *Pusey, S. E. B. Bouverie-. Pusey House, Faringdon.
1868. §PYE-SMITH, P. H., M.D. 56 Harley-street, W.; and Guy's Hospital, London, S.E.
1861. *Pyne, Joseph John. St. German's Villa, St. Lawrence-road, Notting-hill, W.

1870. ‡Rabbits, W. T. Forest-hill, London, S.E.
1860. ‡RADCLIFFE, CHARLES BLAND, M.D. 25 Cavendish-square, London, W.
1870. ‡Radcliffe, D. R. Phœnix Safe Works, Windsor, Liverpool.
*Radford, William, M.D. Sidmount, Sidmouth.
1861. ‡*Rafferty, Thomas.*
1854. ‡Raffles, Thomas Stamford. 13 Abercromby-square, Liverpool.
1870. ‡Raffles, William Winter. Sunnyside, Prince's Park, Liverpool.
1855. ‡Rainey, Harry, M.D. 10 Moore-place, Glasgow.
1864. ‡Rainey, James T. St. George's Lodge, Bath.
Rake, Joseph. Charlotte-street, Bristol.
1863. ‡RAMSAY, ALEXANDER, F.G.S. Kilmorey Lodge, 6 Kent-gardens, Ealing, W.
1845. ‡RAMSAY, ANDREW CROMBIE, LL.D., F.R.S., F.G.S., Director-General of the Geological Survey of the United Kingdom and of the Museum of Economic Geology; Professor of Geology in the Royal School of Mines. Geological Survey Office, Jermyn-street, London, S.W.
1863. ‡*Ramsay, D. R.*
1867. ‡Ramsay, James, jun. Dundee.
1861. ‡Ramsay, John. Kildalton, Argyleshire.
1867. *Ramsay, W. F., M.D. 15 Somerset-street, Portman-square, London, W.
1873. *Ramsden, William. Bracken Hall, Great Horton, Bradford, Yorkshire.
1835. *Rance, Henry (Solicitor). Cambridge.
1869. *Rance, H. W. Henniker, LL.M. 62 St. Andrew's-street, Cambridge.
1860. ‡Randall, Thomas. Grandepoint House, Oxford.
1865. ‡Randel, J. 50 Vittoria-street, Birmingham.
1855. ‡Randolph, Charles. Pollockshiels, Glasgow.
Ranelagh, The Right Hon. Lord. 7 New Burlington-street, Regent-street, London, W.
1868. *Ransom, Edwin, F.R.G.S. Kempstone Mill, Bedford.
1863. §Ransom, William Henry, M.D., F.R.S. The Pavement, Nottingham.
1861. ‡Ransome, Arthur, M.A. Bowdon, Manchester.
Ransome, Thomas. 34 Princess-street, Manchester.
1872. *Ranyard, Arthur Cowper, F.R.A.S. 25 Old-square, Lincoln's-Inn, London, W.C.
Rashleigh, Jonathan. 3 Cumberland-terrace, Regent's Park, London, N.W.
*RATCLIFF, Colonel CHARLES, F.L.S., F.G.S., F.S.A., F.R.G.S. Wyddrington, Edgbaston, Birmingham.
1864. §Rate, Rev. John, M.A. Lapley Vicarage, Penkridge, Staffordshire.
1870. ‡Rathbone, Benson. Exchange-buildings, Liverpool.
1870. ‡Rathbone, Philip H. Greenbank Cottage, Wavertree, Liverpool.

Year of
Election.
1870. §Rathbone, R. R. Beechwood House, Liverpool.
1863. ‡Rattray, W. St. Clement's Chemical Works, Aberdeen.
1874. ‡Ravenstein, E. G., F.R.G.S. 10 Lorn-road, Brixton, London, S.W.
Rawdon, William Frederick M.D. Bootham, York.
1870. ‡Rawlins, G. W. The Hollies, Rainhill, Liverpool.
*Rawlins, John. Shrawley Wood House, near Stourport.
1866. *RAWLINSON, Rev. Canon GEORGE, M.A., Camden Professor of Ancient History in the University of Oxford. The Oaks, Precincts, Canterbury.
1855. *RAWLINSON, Major-General Sir HENRY C., K.C.B., LL.D., F.R.S., F.R.G.S. 21 Charles-street, Berkeley-square, London, W.
1875. §Rawson, Sir Rawson W., K.C.M.G., C.B. Newlands House, Sydenhem, S.E.
1868. *RAYLEIGH, The Right Hon. Lord, M.A., F.R.S. 4 Carlton-gardens, Pall Mall, London, S.W.; and Terling Place, Witham, Essex.
1865. ‡Rayner, Henry. West View, Liverpool-road, Chester.
1870. ‡Rayner, Joseph (Town Clerk). Liverpool.
1852. ‡Read, Thomas, M.D. Donegal-square West, Belfast.
1865. ‡Read, William. Albion House, Epworth, Bawtry.
*Read, W. H. Rudston, M.A., F.L.S. 12 Blake-street, York.
1870. §Reade, Thomas M., C.E., F.G.S. Blundellsands, Liverpool.
1862. *Readwin, Thomas Allison, M.R.I.A., F.G.S. 37 Osborne-road, Tuebrook, Liverpool.
1852. *REDFERN, Professor PETER, M.D. 4 Lower-crescent, Belfast.
1863. ‡Redmayne, Giles. 20 New Bond-street, London, W.
1863. ‡Redmayne, R. R. 12 Victoria-terrace, Newcastle-on-Tyne.
Redwood, Isaac. Cae Wern, near Neath, South Wales.
1861. *Reé, H. P. Villa Ditton, Torquay.
1861. ‡REED, EDWARD J., Vice-President of the Institute of Naval Architects. Chorlton-street, Manchester.
1875. §Rees-Mogg, W. Wooldridge. Cholwell House, near Bristol.
1869. ‡*Reid, J. Wyatt.*
1874. ‡Reid, Robert, M.A. 35 Dublin-road, Belfast.
1850. ‡Reid, William, M.D. Cruivie, Cupar, Fife.
1875. §Reinold, A. W., M.A., Professor of Physical Science. Royal Naval College, Greenwich, S.E.
1863. §Renals, E. 'Nottingham Express' Office, Nottingham.
1863. ‡Rendel, G. Benwell, Newcastle-on-Tyne.
1867. ‡Renny, W. W. 8 Douglas-terrace, Broughty Ferry, Dundee.
1869. ‡*Révy, J. J. 16 Great George-street, Westminster, S. W.*
1871. ‡REYNOLDS, Professor JAMES EMERSON, M.A., F.C.S. Royal Dublin Society, Kildare-street, Dublin.
1870. *REYNOLDS, OSBORNE, M.A., Professor of Engineering in Owens College, Manchester. Fallowfield, Manchester.
1858. §Reynolds, Richard, F.C.S. 13 Briggate, Leeds.
Reynolds, William, M.D.
1858. *Rhodes, John. 18 Albion-street, Leeds.
1868. §RICHARDS, Rear-Admiral GEORGE H., C.B., F.R.S., F.R.G.S. The Athenæum Club, London, S.W.
1863. §RICHARDSON, BENJAMIN WARD, M.A., M.D., F.R.S. 12 Hinde-street, Manchester-square, London, W.
1861. §Richardson, Charles. 10 Berkeley-square, Bristol.
1869. *Richardson, Charles. Albert Park, Abingdon, Berks.
1863. *Richardson, Edward. 6 Stanley-terrace, Gosforth, Newcastle-on-Tyne.
1868. *Richardson, George. 4 Edward-street, Werneth, Oldham.
1870. ‡Richardson, J. H. 3 Arundel-terrace, Cork.

Year of
Election.

1868. ‡*Richardson, James C.*
1863. ‡*Richardson, John. W.*
1870. ‡Richardson, Ralph. 16 Coates-crescent, Edinburgh.
Richardson, Thomas. Montpelier-hill, Dublin.
Richardson, William. Micklegate, York.
1861. §Richardson, William. 4 Edward-street, Werneth, Oldham.
1861. ‡Richson, Rev. Canon, M.A. Shakespeare-street, Ardwick, Manchester.
1863. ‡Richter, Otto, Ph.D. 7 India-street, Edinburgh.
1870. ‡Rickards, Dr. 36 Upper Parliament-street, Liverpool.
1868. §RICKETTS, CHARLES, M.D., F.G.S. 22 Argyle-street, Birkenhead.
*RIDDELL, Major-General CHARLES J. BUCHANAN, C.B., R.A., F.R.S. Oaklands, Chudleigh, Devon.
1861. *Riddell, Henry B. Whitefield House, Rothbury, Morpeth.
1859. ‡Riddell, Rev. John. Moffat by Beatlock, N.B.
1861. *Rideout, William J. 51 Charles-street, Berkeley-square, London, W.
1872. ‡Ridge, James. 98 Queen's-road, Brighton.
1862. ‡Ridgway, Henry Akroyd, B.A. Bank Field, Halifax.
1861. ‡Ridley, John. 19 Belsize-park, Hampstead, London, N.W.
1863. *Rigby, Samuel. Bruche Hall, Warrington.
1873. ‡Ripley, Edward. Acacia, Apperley, near Leeds.
1873. §Ripley, H. W. Acacia, Apperley, near Leeds.
*RIPON, The Marquis of, K.G., D.C.L., F.R.S., F.L.S. 1 Carlton-gardens, London, S.W.
1860. ‡Ritchie, George Robert. 4 Watkyn-terrace, Coldharbour-lane, Camberwell, London, S.E.
1867. ‡Ritchie, John. Fleuchar Craig, Dundee.
1855. ‡Ritchie, Robert, C.E. 14 Hill-street, Edinburgh.
1867. ‡Ritchie, William. Emslea, Dundee.
1869. *Rivington, John. Great Milton, Tetsworth, Oxon.
1854. ‡Robberds, Rev. John, B.A. Battledown Tower, Cheltenham.
1869. *ROBBINS, J., F.C.S. 57 Warrington-crescent, Maida-vale, London, N.W.
Roberton, John. Oxford-road, Manchester.
1859. ‡Roberts, George Christopher. Hull.
1859. ‡Roberts, Henry, F.S.A. Athenæum Club, London, S.W.
1870. *Roberts, Isaac, F.G.S. 26 Rock-park, Rock-ferry, Cheshire.
1857. ‡Roberts, Michael, M.A. Trinity College, Dublin.
1868. §ROBERTS, W. CHANDLER, F.R.S., F.G.S., F.C.S. Royal Mint, London, E.
**Roberts, William P.*
1866. ‡Robertson, Alister Stuart, M.D., F.R.G.S. Horwich, Bolton, Lancashire.
1859. ‡Robertson, Dr. Andrew. Indego, Aberdeen.
1867. §Robertson, David. Union Grove, Dundee.
1871. ‡Robertson, George, C.E., F.R.S.E. 47 Albany-street, Edinburgh.
1870. *Robertson, John. Bank, High-street, Manchester.
1866. ‡ROBERTSON, WILLIAM TINDAL, M.D. Nottingham.
1861. ‡Robinson, Enoch. Dukinfield, Ashton-under-Lyne.
1852. ‡Robinson, Rev. George. Tartaragham Glebe, Loughgall, Ireland.
1859. ‡Robinson, Hardy. 156 Union-street, Aberdeen.
*Robinson, H. Oliver. 34 Bishopsgate-street, London, E.C.
1873. §Robinson, Hugh. 3 Donegal-street, Belfast.
1866. ‡*Robinson, John.*
1861. ‡Robinson, John. Atlas Works, Manchester.
1863. ‡Robinson, J. H. Cumberland-row, Newcastle-on-Tyne.
1855. ‡*Robinson, M. E. 116 St. Vincent-street, Glasgow.*
1875. §Robinson, Robert, C.E. Darlington.

Year of Election.

1860. ‡Robinson, Admiral Sir Robert Spencer, K.C.B., F.R.S. 61 Eaton-place, London, S.W.
ROBINSON, Rev. THOMAS ROMNEY, D.D., F.R.S., F.R.A.S., M.R.I.A., Director of the Armagh Observatory. Armagh.
1863. ‡Robinson, T. W. U. Houghton-le-Spring, Durham.
1870. ‡Robinson, William. 40 Smithdown-road, Liverpool.
1870. *Robson, E. R. 20 Great George-street, Westminster, S.W.
*Robson, Rev. John, M.A., D.D Ajmére Lodge, Cathkin-road, Langside, Glasgow.
1855. ‡Robson, Neil, C.E. 127 St. Vincent-street, Glasgow.
1872. *Robson, William. 3 Palmerston-road, Grange, Edinburgh.
1872. §RODWELL, GEORGE F., F.R.A.S., F.C.S. Marlborough College, Wiltshire.
1866. ‡Roe, Thomas. Grove-villas, Sitchurch.
1861. §ROFE, JOHN, F.G.S. 9 Crosbie-terrace, Leamington.
1860. ‡ROGERS, JAMES E. THOROLD, Professor of Economic Science and Statistics in King's College, London. Beaumont-street, Oxford.
1867. ‡Rogers, James S Rosemill, by Dundee.
1869. *Rogers, Nathaniel, M.D. 87 South-street, Exeter.
1870. ‡Rogers, T. L., M.D. Rainhill, Liverpool.
1859. ‡ROLLESTON, GEORGE, M.A., M.D., F.R.S., F.L.S., Professor of Anatomy and Physiology in the University of Oxford. The Park, Oxford.
1866. ‡Rolph, George Frederick. War Office, Horse Guards, London, S.W.
1863. ‡Romilly, Edward. 14 Hyde Park-terrace, London, W.
1846. ‡Ronalds, Edmund, Ph.D. Stewartfield, Bonnington, Edinburgh.
1869. ‡Roper, C. H. Magdalen-street, Exeter.
1872. *Roper, Freeman Clark Samuel, F.L.S., F.G.S. Palgrave House, Eastbourne.
1855. *ROSCOE, HENRY ENFIELD, B.A., Ph.D., F.R.S., F.C.S., Professor of Chemistry in Owens College, Manchester.
1863. ‡Roseby, John. Haverholme House, Brigg, Lincolnshire.
1874. ‡Ross, Alex. Milton, M.A., M.D., F.G.S. Toronto, Canada.
1857. ‡Ross, David, LL.D. Drumbrain Cottage, Newbliss, Ireland.
1872. §Ross, James, M.D. Tenterfield House, Waterfoot, near Manchester.
1859. *Ross, Rev. James Coulman. Baldon Vicarage, Oxford.
1861. *Ross, Thomas. 7 Wigmore-street, Cavendish-square, London, W.
1842. *Ross, William.*
1874. §Ross, Rev. William. Chapelhill Manse, Rothesay, Scotland.
1869. *ROSSE, The Right Hon. The Earl of, D.C.L., F.R.S., F.R.A.S. Birr Castle, Parsonstown, Ireland; and 32 Lowndes-square, London, S.W.
1865. *Rothera, George Bell. 17 Waverley-street, Nottingham.
1861. ‡Routh, Edward J., M.A., F.R.S., F.R.A.S., F.G.S. St. Peter's College, Cambridge.
1872. *Row, A. V. Nursing Observatory, Daba-gardens, Vizagapatam, India. (Care of Messrs. King & Co., 45 Pall Mall, London, S.W.)
1861. ‡Rowan, David. Elliot-street, Glasgow.
1855. ‡*Rowand, Alexander.*
1865. §Rowe, Rev. John. Load Vicarage, Langport, Somerset.
1855. *ROWNEY, THOMAS H., Ph.D., F.C.S., Professor of Chemistry in Queen's College, Galway. Salerno, Salt Hill, Galway.
*Rowntree, Joseph. 13 Castle-gate, York.
1862. ‡Rowsell, Rev. Evan Edward, M.A. Hambledon Rectory, Godalming.
1861. *Royle, Peter, M.D., L.R.C.P., M.R.C.S. 27 Lever-street, Manchester.

Year of Election.

1875. §Rücker, A. W. Yorkshire College of Science, Leeds.
1869. §Rudler, F. W., F.G.S. The Museum, Jermyn-street, London, S.W.
1856. ‡Rumsey, Henry Wyldbore, M.D., F.R.S., F.R.C.S. Knoll Hill, Prestbury, near Cheltenham.
1873. ‡Rushforth, Joseph. 43 Ash-grove, Horton-lane, Bradford, Yorkshire.
1847. ‡RUSKIN, JOHN, M.A., F.G.S., Slade Professor of Fine Arts in the University of Oxford. Corpus Christi College, Oxford.
1857. ‡Russell, Rev. C. W., D.D. Maynooth College.
1875. *Russell, F. A. R. Pembroke Lodge, Richmond Park, Surrey.
1865. ‡Russell, James, M.D. 91 Newhall-street, Birmingham.
1859. ‡RUSSELL, The Right Hon. JOHN, Earl, K.G., F.R.S., F.R.G.S. 37 Chesham-place, Belgrave-square, London, S.W.
Russell, John.
RUSSELL, JOHN SCOTT, M.A., F.R.S. L. & E. Sydenham; and 5 Westminster Chambers, London, S.W.
1852. *Russell, Norman Scott. 5 Westminster-chambers, London, S.W.
1862. §RUSSELL, W. H. L., A.B., F.R.S. 5 The Grove, Highgate, London, N.
1852. *RUSSELL, WILLIAM J., Ph.D., F.R.S., F.C.S., Professor of Chemistry, St. Bartholomew's Medical College. 34 Upper Hamilton-terrace, St. John's Wood, London, N.W.
1865. ‡Rust, Rev. James, M.A. Manse of Slains, Ellon, N.B.
1875. §Rutherford, David Greig. Surrey House, Forest Hill, London, S.E.
1871. §RUTHERFORD, WILLIAM, M.D., F.R.S.E., Professor of the Institutes of Medicine in the University of Edinburgh.
Rutson, William. Newby Wiske, Northallerton, Yorkshire.
1871. ‡*Ruttledge, T. E.*
1875. §Ryalls, Charles Wager, LL.D. 3 Brick-court, Temple, London, E.C.
1874. §Rye, E. C., F.Z.S., Librarian R.G.S. Parkfield, Putney, London, S.W.
*Ryland, Arthur. The Linthurst Hill, Broomsgrove, Worcestershire.
1865. ‡Ryland, Thomas. The Redlands, Erdington, Birmingham.
1853. ‡*Rylands, Joseph.*
1861. *RYLANDS, THOMAS GLAZEBROOK, F.L.S., F.G.S. Highfields, Thelwall, near Warrington.

*SABINE, General Sir EDWARD, K.C.B., R.A., LL.D., D.C.L., F.R.S., F.R.A.S., F.L.S., F.R.G.S. 13 Ashley-place, Westminster, S.W.
1865. ‡Sabine, Robert. Auckland House, Willesden-lane, London, N.W.
1871. §Sadler, Samuel Champernowne. Purton Court, Purton, near Swindon, Wiltshire.
1866. *St. Albans, His Grace the Duke of. Bestwood Lodge, Arnold, near Nottingham.
Salkeld, Joseph. Penrith, Cumberland.
1857. ‡SALMON, Rev. GEORGE, D.D., D.C.L., F.R.S., Regius Professor of Divinity in the University of Dublin. Trinity College, Dublin.
1873. *Salomons, Sir David, Bart. Broom-hill, Tunbridge Wells.
1858. *SALT, Sir TITUS, Bart. Crow-Nest, Lightcliffe, near Halifax.
1872. ‡SALVIN, OSBERT, M.A., F.R.S., F.L.S. Brookland Avenue, Cambridge.
1842. Sambrooke, T. G. 32 Eaton-place, London, S.W.
1861. *Samson, Henry. 6 St. Peter's-square, Manchester.
1867. ‡Samuelson, Edward. Roby, near Liverpool.
1870. ‡SAMUELSON, JAMES. St. Domingo-grove, Everton, Liverpool.
1861. *Sandeman, Archibald, M.A. Tulloch, Perth.
1857. ‡Sanders, Gilbert. The Hill, Monkstown, Co. Dublin.
1872. ‡Sanders, Mrs. 8 Powis-square, Brighton.

Year of Election.
1871. ‡Sanders, William R., M.D. 11 Walker-street, Edinburgh.
1872. §SANDERSON, J. S. BURDON, M.D., F.R.S., Professor of Physiology in University College, London. 49 Queen Anne-street, London, W.
Sandes, Thomas, A.B. Sallow Glin, Tarbert, Co. Kerry.
1864. ‡Sandford, William. 9 Springfield-place, Bath.
1854. ‡Sandon, The Right Hon. Lord, M.P. 39 Gloucester-square, London, W.
1873. ‡Sands, T. C. 24 Spring-gardens, Bradford, Yorkshire.
1865. ‡Sargant, W. L. Edmund-street, Birmingham.
Satterfield, Joshua. Alderley Edge.
1868. ‡Saunders, A., C.E. King's Lynn.
1846. ‡Saunders, Trelawney W. India Office, London, S.W.
1864. ‡Saunders, T. W., Recorder of Bath. 1 Priory-place, Bath.
1860. *Saunders, William. 3 Gladstone-terrace, Brighton.
1871. §Savage, W. D. Ellerslie House, Brighton.
1863. ‡Savory, Valentine. Cleckheaton, near Leeds.
1872. §Sawyer, George David. 55 Buckingham-place, Brighton.
1868. ‡Sawyer, John Robert. Grove-terrace, Thorpe Hamlet, Norwich.
1857. ‡*Scallan, J. Joseph.*
1850. ‡Scarth, Pillans. 2 James's-place, Leith.
1868. §Schacht, G. F. 7 Regent's-place, Clifton, Bristol.
1872. ‡SCHENCK, ROBERT, Ph.D. 398 Manor-terrace, Brixton, London, S.W.
1842. Schofield, Joseph. Stubley Hall, Littleborough, Lancashire.
1874. §Scholefield, Henry. Windsor-crescent, Newcastle-on-Tyne.
*Scholes, T. Seddon. 10 Warwick-place, Leamington.
SCHUNCK, EDWARD, F.R.S., F.C.S. Oaklands, Kersall Moor, Manchester.
1873. *Schuster, Arthur, Ph.D. Sunnyside, Upper Avenue-road, Regent's Park, London, N.W.
1861. *Schwabe, Edmund Salis. Ryecroft House, Cheetham Hill, Manchester.
1847. ‡SCLATER, PHILIP LUTLEY, M.A., Ph.D., F.R.S., F.L.S., Sec. Zool. Soc. 11 Hanover-square, London, W.
1867. ‡SCOTT, ALEXANDER. Clydesdale Bank, Dundee.
1871. ‡Scott, Rev. C. G. 12 Pilrig-street, Edinburgh.
1859. ‡*Scott, Captain Fitzmaurice. Forfar Artillery.*
1872. §Scott, Major-General H. Y. D., C.B., R.E., F.R.S. Sunnyside, Ealing, W.
1871. ‡Scott, James S. T. Monkrigg, Haddingtonshire.
1857. §SCOTT, ROBERT H., M.A., F.R.S., F.G.S., F.M.S., Director of the Meteorological Office. 116 Victoria-street, London, S.W.
1861. §Scott, Rev. Robert Selkirk, D.D. 16 Victoria-crescent, Dowanhill, Glasgow.
1874. ‡Scott, Rev. Robinson, D.D. Methodist College, Belfast.
1864. ‡Scott, Wentworth Lascelles. Wolverhampton.
1858. ‡Scott, William. Holbeck, near Leeds.
1869. §Scott, William Bower. Chudleigh, Devon.
1864. ‡Scott, William Robson, Ph.D. St. Leonards, Exeter.
1869. ‡Searle, Francis Furlong. 5 Cathedral-yard, Exeter.
1859. ‡Seaton, John Love. Hull.
1870. ‡*Seaton, Joseph, M.D.*
1861. *SEELEY, HARRY GOVIER, F.L.S., F.G.S., Professor of Physical Geography, Bedford College, London. 61 Adelaide-road, South Hampstead, London, N.W.
1855. ‡Seligman, H. L. 135 Buchanan-street, Glasgow.
1873. ‡Semple, R. H., M.D. 8 Torrington-square, London, W.C.

Year of Election.

1858. *Senior, George, F.S.S. Rosehill Lodge, Dodworth, near Barnsley.
1870. *Sephton, Rev. J. 92 Huskisson-street, Liverpool.
1875. §Seville, Thomas. Elm House, Royton, near Manchester.
1873. §Sewell, Rev. E., M.A., F.R.G.S. Ilkley College, near Leeds.
1868. ‡Sewell, Philip E. Catton, Norwich.
1861. *Seymour, Henry D. 209 Piccadilly, London, W.
Seymour, John. 21 Bootham, York.
1853. ‡Shackles, G. L. 6 Albion-street, Hull.
*Shaen, William. 15 Upper Phillimore-gardens, Kensington, London, W.
1871. *Shand, James. Fullbrooks, Worcester Park, Surrey.
1867. §Shanks, James. Den Iron Works, Arbroath, N.B.
1869. *Shapter, Dr. Lewis, LL.D. The Barnfield, Exeter.
Sharp, Rev. John, B.A. Horbury, Wakefield.
1861. ‡SHARP, SAMUEL, F.G.S., F.S.A. Dallington Hall, near Northampton.
*Sharp, William, M.D., F.R.S., F.G.S. Horton House, Rugby.
Sharp, Rev. William, B.A. Mareham Rectory, near Boston, Lincolnshire.
SHARPEY, WILLIAM, M.D., LL.D., F.R.S., F.R.S.E. 50 Torrington-square, London, W.C.
1858. *Shaw, Bentley. Woodfield House, Huddersfield.
1854. *Shaw, Charles Wright. 3 Windsor-terrace, Douglas, Isle of Man.
1870. ‡Shaw, Duncan. Cordova, Spain.
1865. ‡Shaw, George. Cannon-street, Birmingham.
1870. ‡Shaw, John. 24 Great George-place, Liverpool.
1845. ‡Shaw, John, M.D., F.L.S., F.G.S. Hop House, Boston, Lincolnshire.
1853. ‡Shaw, Norton, M.D. St. Croix, West Indies.
1839. Shepard, John. 41 Drewton-street, Manningham-road, Bradford, Yorkshire.
1863. ‡Shepherd, A. B. 49 Seymour-street, Portman-square, London, W.
1870. §Shepherd, Joseph. 29 Everton-crescent, Liverpool.
Sheppard, Rev. Henry W., B.A. The Parsonage, Emsworth, Hants.
1869. ‡*Sherard, Rev. S. H.*
1866. ‡Shilton, Samuel Richard Parr. Sneinton House, Nottingham.
1867. ‡Shinn, William C. Her Majesty's Printing Office, near Fetter-lane, London, E.C.
1870. *SHOOLBRED, JAMES N., C.E., F.G.S. 3 Westminster Chambers, London, S.W.
1875. §Shore, Thomas W., F.C.S. Hartley Institution, Southampton.
1842. Shuttleworth, John. Wilton Polygon, Cheetham-hill, Manchester.
1866. ‡SIBSON, FRANCIS, M.D., F.R.S. 59 Brook-street, London, W.
1861. *Sidebotham, Joseph. 19 George-street, Manchester.
1872. *Sidebottom, Robert. Mersey Bank, Heaton Mersey, Manchester.
1873. ‡Sidgwick, R. H. The Raikes, Skipton.
1857. ‡Sidney, Frederick John, LL.D., M.R.I.A. 19 Herbert-street, Dublin.
Sidney, M. J. F. Cowpen, Newcastle-upon-Tyne.
1873. *Siemens, Alexander. 12 Queen Anne's-gate, Westminster, S.W.
1856. *SIEMENS, C. WILLIAM, D.C.L., F.R.S., F.C.S., M.I.C.E. 12 Queen Anne's-gate, Westminster, S.W.
*Sillar, Zechariah, M.D. Bath House, Laurie Park-gardens, Sydenham, London, S.E.
1859. ‡Sim, John. Hardgate, Aberdeen.
1871. ‡Sime, James. Craigmount House, Grange, Edinburgh.

Year of Election.

1865. §Simkiss, T. M. Wolverhampton.
1862. ‡Simms, James. 138 Fleet-street, London, E.C.
1852. †Simms, William. Albion-place, Belfast.
1874. §Simms, William. The Linen Hall, Belfast.
1847. ‡Simon, John, D.C.L., F.R.S., F.R.C.S., Medical Officer of the Privy Council. 40 Kensington-square, London, W.
1866. ‡Simons, George. The Park, Nottingham.
1871. *SIMPSON, ALEXANDER R., M.D., Professor of Midwifery in the University of Edinburgh. 52 Queen-street, Edinburgh.
1867. ‡Simpson, G. B. Seafield, Broughty Ferry, by Dundee.
1859. ‡Simpson, John. Marykirk, Kincardineshire.
1863. ‡Simpson, J. B., F.G.S. Hedgefield House, Blaydon-on-Tyne.
1857. ‡SIMPSON, MAXWELL, M.D., F.R.S., F.C.S., Professor of Chemistry in Queen's College, Cork.
*Simpson, Rev. Samuel. Greaves House, near Lancaster.
Simpson, Thomas. Blake-street, York.
Simpson, William. Bradmore House, Hammersmith, London, W.
1859. ‡Sinclair, Alexander. 133 George-street, Edinburgh.
1874. ‡Sinclair, Thomas. Dunedin, Belfast.
1834. ‡Sinclair, Vetch, M.D. 48 Albany-street, Edinburgh.
1870. *Sinclair, W. P. 19 Devonshire-road, Prince's Park, Liverpool.
1864. *Sircar, Baboo Mohendro Lall, M.D. 1344 San Kany, Tollah-street, Calcutta, per Messrs. Harrenden & Co., 3 Chapel-place, Poultry, London, E.C.
1865. §Sissons, William. 92 Park-street, Hull.
1870. §Sladen, Walter Percy, F.G S. Exley House, near Halifax.
1873. ‡Slater, Clayton. Barnoldswick, near Leeds.
1870. ‡Slater, W. B. 42 Clifton Park-avenue, Belfast.
1842. *Slater, William. Park-lane, Higher Broughton, Manchester.
1853. ‡Sleddon, Francis. 2 Kingston-terrace, Hull.
1849. §Sloper, George Edgar. Devizes.
1849. ‡Sloper, Samuel W. Devizes.
1860. §Sloper, S. Elgar. Winterton, near Hythe, Southampton.
1872. ‡Smale, The Hon. Sir John, Chief Justice of Hong Kong.
1867. ‡Small, David. Gray House, Dundee.
1858. ‡Smeeton, G. H. Commercial-street, Leeds.
1867. ‡Smeiton, John G. Panmure Villa, Broughty Ferry, Dundee.
1867. ‡Smeiton, Thomas A. 55 Cowgate, Dundee.
1868. ‡Smith, Augustus. Northwood House, Church-road, Upper Norwood, Surrey, S.E.
1857. ‡Smith, Aquila, M.D., M.R.I.A. 121 Lower Bagot-street, Dublin.
1872. *Smith, Basil Woodd, F.R.A.S. Branch Hill Lodge, Hampstead-heath, London, N.W.
1874. *Smith, Benjamin Leigh. 64 Gower-street, London, W.C.
1873. ‡Smith, C. Sidney College, Cambridge.
1865. ‡SMITH, DAVID, F.R.A.S. 4 Cherry-street, Birmingham.
1865. ‡Smith, Frederick. The Priory, Dudley.
1866. *Smith, F. C., M.P. Bank, Nottingham.
1855. ‡Smith, George. Port Dundas, Glasgow.
1855. ‡Smith, George Cruickshank. 19 St. Vincent-place, Glasgow.
*SMITH, HENRY JOHN STEPHEN, M.A., F.R.S., F.C.S., Savilian Professor of Geometry in the University of Oxford, and Keeper of the University Museum. The Museum, Oxford.
1860. *Smith, Heywood, M.A., M.D. 2 Portugal-street, Grosvenor-square, London, W.
1865. ‡*Smith, Isaac.*
1870. ‡Smith, James. 146 Bedford-street South, Liverpool.

Year of Election.

1873. ‡*Smith, James.*
1871. *Smith, John Alexander, M.D., F.R.S.E. 10 Palmerston-place, Edinburgh.
1874. ‡Smith, John Haigh. Beech Hill, Halifax, Yorkshire.
1867. *Smith, John P., C.E. 67 Renfield-street, Glasgow.
Smith, John Peter George.
1852. ***Smith, Rev. Joseph Denham.*
1871. ‡Smith, Professor J. William Robertson. Free Church College, Aberdeen.
*Smith, Philip, B.A. 26 South-hill-park, Hampstead, London, N.W.
1860. *Smith, Protheroe, M.D. 42 Park-street, Grosvenor-square, London, W.
1837. Smith, Richard Bryan. Villa Nova, Shrewsbury.
1847. §SMITH, ROBERT ANGUS, Ph.D., F.R.S., F.C.S. 22 Devonshire-street, Manchester.
*Smith, Robert Mackay. 4 Bellevue-crescent, Edinburgh.
1870. ‡Smith, Samuel. Bank of Liverpool, Liverpool.
1866. §Smith, Samuel. 33 Compton-street, Goswell-road, London, E.C.
1873. ‡Smith, Swire. Lowfield, Keighley, Yorkshire.
1867. ‡Smith, Thomas (Sheriff). Dundee.
1867. ‡Smith, Thomas. Pole Park Works, Dundee.
1859. ‡Smith, Thomas James, F.G.S., F.C.S. Hessle, near Hull.
1852. ‡Smith, William. Eglinton Engine Works, Glasgow.
1857. §SMITH, WILLIAM, C.E., F.G.S., F.R.G.S. 18 Salisbury-street, Adelphi, London, W.C.
1875. §Smith, William. Sundon House, Clifton, Bristol.
1874. ‡Smoothy, Frederick. Bocking, Essex.
1850. *SMYTH, CHARLES PIAZZI, F.R.S.E., F.R.A.S., Astronomer Royal for Scotland, Professor of Astronomy in the University of Edinburgh. 15 Royal-terrace, Edinburgh.
1870. ‡Smyth, Colonel H. A., R.A. Barrackpore, near Calcutta.
1874. ‡Smyth, Henry, C.E. Downpatrick, Ireland.
1870. ‡Smyth, H. L. Crabwall Hall, Cheshire.
1857. *SMYTH, JOHN, jun., M.A., M.I.C.E.I., F.M.S. Milltown, Banbridge, Ireland.
1868. ‡Smyth, Rev. J. D. Hurst. 13 Upper St. Giles's-street, Norwich.
1864. ‡SMYTH, WARINGTON W., M.A., F.R.S., F.G.S., F.R.G.S., Lecturer on Mining and Mineralogy at the Royal School of Mines, and Inspector of the Mineral Property of the Crown. 92 Inverness-terrace, Bayswater, London, W.
1854. ‡Smythe, Major-General W. J., R.A., F.R.S. Athenæum Club, Pall Mall, London, S.W.
Soden, John. Athenæum Club, Pall Mall, London, S.W.
*SOLLY, EDWARD, F.R.S., F.L.S., F.G.S., F.S.A. Park House, Sutton, Surrey.
*SOPWITH, THOMAS, M.A., F.R.S., F.G.S., F.R.G.S. 103 Victoria-street, Westminster, S.W.
Sorbey, Alfred. The Rookery, Ashford, Bakewell.
1859. *SORBY, H. CLIFTON, F.R.S., F.G.S. Broomfield, Sheffield.
1865. *Southall, John Tertius. Leominster.
1859. ‡Southall, Norman. 44 Cannon-street West, London, E.C.
1856. ‡Southwood, Rev. T. A. Cheltenham College.
1863. ‡Sowerby, John. Shipcote House, Gateshead, Durham.
1863. *Spark, H. King. Skirsgill Park, Penrith.
1859. ‡Spence, Rev. James, D.D. 6 Clapton-square, London, N.E.
*Spence, Joseph. 60 Holgate Hill, York.

Year of Election.

1869. *Spence, J. Berger. Erlington House, Manchester.
1854. §Spence, Peter. Pendleton Alum Works, Newton Heath; and Smedley Hall, near Manchester.
1861. ‡Spencer, John Frederick. 28 Great George-street, London, S.W.
1861. *Spencer, Joseph. Bute House, Old Trafford, Manchester.
1863. *Spencer, Thomas. The Grove, Ryton, Blaydon-on-Tyne, Co. Durham.
1875. §Spencer, W. H. Richmond-hill, Clifton, Bristol.
1855. ‡Spens, William. 78 St. Vincent-street, Glasgow.
1871. ‡Spicer, George. Broomfield, Halifax.
1864. *Spicer, Henry, jun., B.A., F.L.S., F.G.S. 14 Aberdeen Park, Highbury, London, N.
1864. §Spicer, William R. 19 New Bridge-street, Blackfriars, London, E.C.
1847. *Spiers, Richard James, F.S.A. Huntercombe, Oxford.
1868. *Spiller, Edmund Pim. 3 Furnival's Inn, London, E.C.
1864. *SPILLER, JOHN, F.C.S. 2 St. Mary's-road, Canonbury, London, N.
1846. *SPOTTISWOODE, WILLIAM, M.A., LL.D., F.R.S., F.R.A.S., F.R.G.S. 50 Grosvenor-place, London, S.W.
1864. *Spottiswoode, W. Hugh. 50 Grosvenor-place, London, S.W.
1854. *SPRAGUE, THOMAS BOND. 26 Buckingham-terrace, Edinburgh.
1853. ‡Spratt, Joseph James. West-parade, Hull.
Square, Joseph Elliot, F.G.S. 24 Portland-place, Plymouth.
*Squire, Lovell. The Observatory, Falmouth.
1858. *STAINTON, HENRY T., F.R.S., F.L.S., F.G.S. Mountsfield, Lewisham, S.E.
1865. §STANFORD, EDWARD C. C. Edinbarnet, Dumbartonshire, N.B.
1837. Staniforth, Rev. Thos. Storrs, Windermere.
STANLEY, The Very Rev. ARTHUR PENRHYN, D.D., F.R.S., Dean of Westminster. The Deanery, Westminster, London, S.W
Stapleton, H. M. 1 Mountjoy-place, Dublin.
1866. ‡Starey, Thomas R. Daybrook House, Nottingham.
Staveley, T. K. Ripon, Yorkshire.
1873. *Stead, Charles. The Knoll, Baildon, near Leeds.
1857. ‡Steale, William Edward, M.D. 15 Hatch-street, Dublin.
1870. ‡Stearn, C. H. 3 Elden-terrace, Rock Ferry, Liverpool.
1863. §Steele, Rev. Dr. 35 Sydney-buildings, Bath.
1873. §Steinthal, G. A. 15 Hallfield-road, Bradford, Yorkshire.
1861. ‡Steinthal, H. M. Hollywood, Fallowfield, near Manchester.
STENHOUSE, JOHN, LL.D., F.R.S., F.C.S. 17 Rodney-street, Pentonville, London, N.
1872. ‡Stennett, Mrs. Eliza. 2 Clarendon-terrace, Brighton.
1875. §Stephens, Walter L. 5 Cambridge Park, Redlands, Bristol.
1861. *Stern, S. J. Littlegrove, East Barnet, Herts.
1863. §Sterriker, John. Driffield.
1872. §Sterry, William. Union Club, Pall Mall, London, S.W.
1870. *Stevens, Miss Anna Maria. Belmont, Devizes-road, Salisbury.
1861. *Stevens, Henry, F.S.A., F.R.G.S. 4 Trafalgar-square, London, W.C.
1863. *Stevenson, Archibald. 2 Wellington-crescent, South Shields.
1850. ‡*Stevenson, David.*
1868. ‡Stevenson, Henry, F.L.S. Newmarket-road, Norwich.
1863. *STEVENSON, JAMES C., M.P. Westoe, South Shields.
1855. ‡STEWART, BALFOUR, M.A., LL.D., F.R.S., Professor of Natural Philosophy in Owens College, Manchester.
1864. ‡STEWART, CHARLES, F.L.S. 19 Princess-square, Plymouth.

Year of Election.
1856. *Stewart, Henry Hutchinson, M.D., M.R.I.A. 75 Eccles-street, Dublin.
1847. ‡Stewart, Robert, M.D. The Asylum, Belfast.
1867. ‡Stirling, Dr. D. Perth.
1868. ‡Stirling, Edward. 34 Queen's-gardens, Hyde Park, London, W.
1867. *Stirrup, Mark. 14 Atkinson-street, Deangate, Manchester.
1865. *Stock, Joseph S. Showell Green, Spark Hill, near Birmingham.
Stoddart, George.
1864. §STODDART, WILLIAM WALTER, F.G.S., F.C.S. 7 King-square, Bristol.
1854. ‡Stoess, Le Chevalier Ch. de W. (Bavarian Consul). Liverpool.
*STOKES, GEORGE GABRIEL, M.A., D.C.L., LL.D., Sec. R.S., Lucasian Professor of Mathematics in the University of Cambrdge. Lensfield Cottage, Cambridge.
1862. ‡STONE, EDWARD JAMES, M.A., F.R.S., F.R.A.S., Astronomer Royal at the Cape of Good Hope. Cape Town.
1874. §Stone, J. F. M. H., F.L.S. St. Peter's College, Cambridge.
1859. ‡*Stone, Dr. William H. 13 Vigo-street, London, W.*
1857. ‡STONEY, BINDON B., M.R.I.A., Engineer of the Port of Dublin. 42 Wellington-road, Dublin.
1861. *STONEY, GEORGE JOHNSTONE, M.A., F.R.S., M.R.I.A., Secretary to the Queen's University, Ireland. Weston House, Dundrum, Co. Dublin.
1854. ‡Store, George. Prospect House, Fairfield, Liverpool.
1873. ‡Storr, William. The 'Times' Office, Printing-house-square, London, E.C.
1867. ‡STORRAR, JOHN, M.D. Heathview, Hampstead, London, N.W.
1859. §Story, James. 17 Bryanston-square, London, W.
1874. §Stott, William. Greetland, near Halifax, Yorkshire.
1871. *STRACHEY, Major-General RICHARD, R.E., C.S.I., F.R.S., F.R.G.S., F.L.S., F.G.S. Stowey House, Clapham Common, London, S.W.
1863. ‡Straker, John. Wellington House, Durham.
*Strickland, Charles. Loughglyn House, Castlerea, Ireland.
Strickland, William. French-park, Roscommon, Ireland.
1859. ‡Stronach, William, R.E. Ardmellie, Banff.
1867. ‡Stronner, D. 14 Princess-street, Dundee.
1866. *STRUTT, The Hon. ARTHUR, F.G.S. Milford House, Derby.
1872. *Stuart, Edward A. Sudbury-hill, Harrow.
1864. ‡Style, Sir Charles, Bart. 102 New Sydney-place, Bath.
1873. §Style, George, M.A. Giggleswick School, Yorkshire.
1857. ‡SULLIVAN, WILLIAM K., Ph.D., M.R.I.A. Royal College of Science for Ireland; and 53 Upper Leeson-road, Dublin.
1873. ‡Sutcliffe, J. W. Sprink Bank, Bradford, Yorkshire.
1873. ‡Sutcliffe, Robert. Idle, near Leeds.
1863. ‡Sutherland, Benjamin John. 10 Oxford-street, Newcastle-on-Tyne.
1862. *SUTHERLAND, GEORGE GRANVILLE WILLIAM, Duke of, K.G., F.R.S., F.R.G.S. Stafford House, London, S.W.
1855. ‡*Sutton, Edwin.*
1868. ‡SUTTON, FRANCIS, F.C.S. Bank Plain, Norwich.
1861. *Swan, Patrick Don S. Kirkcaldy, N.B.
1862. *SWAN, WILLIAM, LL.D., F.R.S.E., Professor of Natural Philosophy in the University of St. Andrews. 2 Hope-street, St. Andrews, N.B.
1862. *Swann, Rev. S. Kirke. Gedling, near Nottingham.
Sweetman, Walter, M.A., M.R.I.A. 4 Mountjoy-square North, Dublin.
1870. *Swinburne, Sir John, Bart. Capheaton, Newcastle-on-Tyne.
1863. ‡Swindell, J. S. E. Summerhill, Kingswinford, Dudley.

Year of Election.

1873. *Swinglehurst, Henry. Hincaster House, near Milnthorpe.
1863. ‡SWINHOE, ROBERT, F.R.G.S., Her Majesty's Consul at Taiwan. 33 Carlyle-square, S.W.; and Oriental Club, London, W.
1873. §Sykes, Benjamin Clifford, M.D. Cleckheaton.
1847. ‡Sykes, H. P. 47 Albion-street, Hyde Park, London, W.
1862. ‡Sykes, Thomas. Cleckheaton, near Leeds.
1847. ‡Sykes, Captain W. H. F. 47 Albion-street, Hyde Park, London, W.
SYLVESTER, JAMES JOSEPH, M.A., LL.D., F.R.S. 60 Maddox-street, W.; and Athenæum Club, London, S.W.
1870. §SYMES, RICHARD GLASCOTT, A.B., F.G.S., Geological Survey of Ireland. 14 Hume-street, Dublin.
1856. *Symonds, Frederick, F.R.C.S. 35 Beaumont-street, Oxford.
1859. ‡Symonds, Captain Thomas Edward, R.N. 10 Adam-street, Adelphi, London, W.C.
1860. ‡SYMONDS, Rev. W. S., M.A., F.G.S. Pendock Rectory, Worcestershire.
1859. §SYMONS, G. J., Sec. M.S. 62 Camden-square, London, N.W.
1855. *SYMONS, WILLIAM, F.C.S. 26 Joy-street, Barnstaple.
Synge, Francis. Glanmore, Ashford, Co. Wicklow.
1872. ‡Synge, Major-General Millington, R.E., F.S.A., F.R.G.S. United Service Club, Pall Mall, London, S.W.

1865. ‡Tailyour, Colonel Renny, R.E. Newmanswalls, Montrose, N.B.
1871. ‡TAIT, PETER GUTHRIE, F.R.S.E., Professor of Natural Philosophy in the University of Edinburgh. 17 Drummond-place, Edinburgh.
1867. ‡Tait, P. M., F.R.G.S. Oriental Club, Hanover-square, London, W.
§Talbot, William Hawkshead. Hartwood Hall, Chorley, Lancashire.
TALBOT, WILLIAM HENRY FOX, M.A., LL.D., F.R.S., F.L.S. Lacock Abbey, near Chippenham.
1874. §Talmage, C. G. Leyton Observatory, Essex, E.
Taprell, William. 7 Westbourne-crescent, Hyde Park, London, W.
1866. ‡Tarbottom, Marrott Ogle, M.I.C.E., F.G.S. Newstead-grove, Nottingham.
1861. *Tarratt, Henry W. Bushbury Lodge, Leamington.
1856. ‡Tartt, William Macdonald, F.S.S. Sandford-place, Cheltenham.
1857. *Tate, Alexander. 2 Queen's-elms, Belfast.
1863. ‡Tate, John. Alnmouth, near Alnwick, Northumberland.
1870. ‡Tate, Norman A. 7 Nivell-chambers, Fazackerley-street, Liverpool.
1865. ‡*Tate, Thomas.*
1858. *Tatham, George. Springfield Mount, Leeds.
1864. *TAWNEY, EDWARD B., F.G.S. 16 Royal-crescent, Clifton, Bristol.
1871. ‡Tayler, William, F.S.A., F.S.S. 28 Park-street, Grosvenor-square, London, W.
1874. ‡Taylor, Alexander O'Driscoll. 3 Upper-crescent, Belfast.
1867. ‡Taylor, Rev. Andrew. Dundee.
Taylor, Frederick. Laurel-cottage, Rainhill, near Prescot, Lancashire.
1874. ‡Taylor, G. P. Students' Chambers, Belfast.
*Taylor, James. Culverlands, near Reading.
*TAYLOR, JOHN, F.G.S. 6 Queen-street-place, Upper Thames-street, London, E.C.
1861. *Taylor, John, jun. 6 Queen-street-place, Upper Thames-street, London, E.C.
1873. §TAYLOR, JOHN ELLOR, F.L.S., F.G.S. The Mount, Ipswich.

Year of Election.

1865. ‡Taylor, Joseph. 99 Constitution-hill, Birmingham.
Taylor, Captain P. Meadows, in the Service of His Highness the Nizam. Harold Cross, Dublin.
*TAYLOR, RICHARD, F.G.S. 6 Queen-street-place, Upper Thames-street, London, E.C.
1870. §Taylor, Thomas. Aston Rowant, Tetsworth, Oxon.
*Taylor, William Edward. Millfield House, Enfield, near Accrington.
1858. ‡Teale, Thomas Pridgin, jun. 20 Park-row, Leeds.
1869. ‡Teesdale, C. S. M. Pennsylvannia, Exeter.
1863. ‡Tennant, Henry. Saltwell, Newcastle-on-Tyne.
*TENNANT, JAMES, F.G.S., F.R.G.S., Professor of Mineralogy in King's College. 149 Strand, London, W.C.
1857. ‡Tennison, Edward King. Kildare-street Club House, Dublin.
1866. ‡Thackeray, J. L. Arno Vale, Nottingham.
1859. ‡Thain, Rev. Alexander. New Machar, Aberdeen.
1871. ‡Thin, James. 7 Rillbank-terrace, Edinburgh.
1871. ‡THISELTON-DYER, W. T., M.A., B.Sc., F.L.S. 10 Gloucester-road, Kew, W.
1835. Thom, John. Lark-hill, Chorley, Lancashire.
1870. ‡Thom, Robert Wilson. Lark-hill, Chorley, Lancashire.
1871. §Thomas, Ascanius William Nevill. Chudleigh, Devon.
1875. *Thomas, Christopher James. Drayton Lodge, Redland, Bristol.
Thomas, George. Brislington, Bristol.
1875. §Thomas Herbert. 2 Great George-street, Bristol.
1869. ‡Thomas, H. D. Fore-street, Exeter.
1869. ‡Thomas, J. Henwood, F.R.G.S. Custom House, London, E.C.
1875. §Thompson, Arthur. 12 St Nicholas-street, Hereford.
*Thompson, Corden, M.D. 84 Norfolk-street, Sheffield.
1863. ‡Thompson, Rev. Francis. St. Giles's, Durham.
1858. *Thompson, Frederick. South-parade, Wakefield.
1859. §Thompson, George, jun. Pidsmedden, Aberdeen.
Thompson, Harry Stephen. Kirby Hall, Great Ouseburn, Yorkshire.
1870. ‡THOMPSON, Sir HENRY. 35 Wimpole-street, London, W.
Thompson, Henry Stafford. Fairfield, near York.
1861. *Thompson, Joseph. Woodlands, Fulshaw, near Manchester.
1864. ‡THOMPSON, Rev. JOSEPH HESSELGRAVE, B.A. Cradley, near Brierley-hill.
Thompson, Leonard. Sheriff-Hutton Park, Yorkshire.
1873. ‡Thompson, M. W. Guiseley, Yorkshire.
1874. §Thompson, Robert. Royal-terrace, Belfast.
1863. ‡Thompson, William. 11 North-terrace, Newcastle-on-Tyne.
1867. ‡Thoms, William. Magdalen-yard-road, Dundee.
1855. ‡THOMSON, ALLEN, M.D., LL.D., F.R.S.L. & E., Professor of Anatomy in the University of Glasgow.
1852. ‡Thomson, Gordon A. Bedeque House, Belfast.
Thomson, Guy. Oxford.
1855. ‡Thomson, James. 82 West Nile-street, Glasgow.
1850. *THOMSON, Professor JAMES, M.A., LL.D., C.E., F.R.S.E. The University, Glasgow.
1868. §THOMSON, JAMES, F.G.S. 276 Eglington-street, Glasgow.
*Thomson, James Gibson. 14 York-place, Edinburgh.
1874. §Thomson, John. Harbour Office, Belfast.
1871. *Thomson, John Millar, F.C.S. King's College, London, W.C.
1863. ‡*Thomson, M.* 8 *Meadow-place, Edinburgh.*
1872. ‡*Thomson, Peter.* 34 *Granville-street, Glasgow.*
1871. ‡Thomson, Robert, LL.B. 12 Rutland-square, Edinburgh.

Year of Election.

1865. ‡Thomson, R. W., C.E., F.R.S.E. 3 Moray-place, Edinburgh.
1850. ‡THOMSON, THOMAS, M.D., F.R.S., F.L.S. The Cottage, West Farleigh, Maidstone.
1874. §Thomson, William, F.C.S. Royal Institution, Manchester.
1847. *THOMSON, Sir WILLIAM, M.A., LL.D., D.C.L., F.R.S.L. & E., Professor of Natural Philosophy in the University of Glasgow. The University, Glasgow.
1871. §Thomson, William Burnes. 11 St. John's-street, Edinburgh.
1870. ‡*Thomson, W. C., M.D.*
1850. ‡THOMSON, WYVILLE T. C., LL.D., F.R.S., F.G.S., Regius Professor of Natural History in the University of Edinburgh. 20 Palmerston-place, Edinburgh.
1871. ‡Thorburn, Rev. David, M.A. 1 John's-place, Leith.
1852. ‡Thorburn, Rev. William Reid, M.A. Starkies, Bury, Lancashire.
1866. ‡Thornton, James. Edwalton, Nottingham.
*Thornton, Samuel. Oakfield, Moseley, near Birmingham.
1867. ‡Thornton, Thomas. Dundee.
1845. ‡Thorp, Dr. Disney. Suffolk Laun, Cheltenham.
1871. ‡Thorp, Henry. Briarleigh, Sale, near Manchester.
*THORP, The Venerable THOMAS, B.D., F.G.S., Archdeacon of Bristol. Kemerton, near Tewkesbury.
1864. *THORP, WILLIAM, B.Sc., F.C.S. 39 Sandringham-road, Kingsland, London, E.
1871. §THORPE, T. E., Ph.D., F.R.S.E., F.C.S., Professor of Chemistry in the Yorkshire College of Science, Leeds.
1868. ‡Thuillier, Colonel, R.A., C.S.I., Surveyor-General of India. 46 Park-street, Calcutta.
Thurnham, John, M.D. Devizes.
1870. ‡Tichborne, Charles R. C., F.C.S. Apothecaries' Hall of Ireland, Dublin.
1873. *TIDDEMAN, R. H., M.A., F.G.S. 28 Jermyn-street, London, S.W.
1874. §Tilden, William A., D.Sc., F.C.S. Clifton College, Bristol.
1873. ‡Tilghman, B. C. Philadelphia, United States.
1865. §Timmins, Samuel, J.P., F.S.A. Elvetham-road, Edgbaston, Birmingham.
Tinker, Ebenezer. Mealhill, near Huddersfield.
*TINNÉ, JOHN A., F.R.G.S. Briarly, Aigburth, Liverpool.
1861. *TODHUNTER, ISAAC, M.A., F.R.S., Principal Mathematical Lecturer at St. John's College, Cambridge. Brookside, Cambridge.
Todhunter, J. 3 College-green, Dublin.
1857. ‡Tombe, Rev. H. J. Ballyfree, Ashford, Co. Wicklow.
1856. ‡Tomes, Robert Fisher. Welford, Stratford-on-Avon.
1864. *TOMLINSON, CHARLES, F.R.S., F.C.S. 3 Ridgmount-terrace, Highgate, London, N.
1863. ‡Tone, John F. Jesmond-villas, Newcastle-on-Tyne.
1865. §Tonks, Edmund, B.C.L. Packwood Grange, Knowle, Warwickshire.
1865. §Tonks, William Henry. The Rookery, Sutton Coldfield.
1873. *Tookey, Charles, F.C.S. Royal School of Mines, Jermyn-street, London, S.W.
1861. *Topham, John, A.I.C.E. High Elms, 265 Mare-street, Hackney, London, E.
1872. *TOPLEY, WILLIAM, F.G.S., A.I.C.E. Geological Survey Office, Jermyn-street, London, S.W.
1875. §Torr, Charles Hawley. Victoria-street, Nottingham.
1863. ‡Torrens, Colonel Sir R. R., K.C.M.G. 2 Gloucester-place, Hyde Park, London, W.

Year of Election.

1859. ‡Torry, Very Rev. John, Dean of St. Andrews. Coupar Angus, N.B.
Towgood, Edward. St. Neot's, Huntingdonshire.
1873. ‡Townend, W. H. Heaton Hall, Bradford, Yorkshire.
1875. §Townsend, Charles. Avenue House, Cotham Park, Bristol.
1860. ‡*Townsend, John.*
1857. ‡TOWNSEND, Rev. RICHARD, M.A., F.R.S., Professor of Natural Philosophy in the University of Dublin. Trinity College, Dublin.
1861. ‡Townsend, William. Attleborough Hall, near Nuneaton.
1854. ‡TOWSON, JOHN THOMAS, F.R.G.S. 47 Upper Parliament-street, Liverpool; and Local Marine Board, Liverpool.
1859. ‡*Trail, Samuel, D.D., LL.D.*
1870. ‡TRAILL, WILLIAM A., M.R.I.A. Geological Survey of Ireland, 14 Hume-street, Dublin.
1875. §Trapnell, Caleb. Severnleigh, Stoke Bishop.
1868. ‡TRAQUAIR, RAMSAY H., M.D., Professor of Zoology, Royal College of Science, Dublin.
1865. ‡Travers, William, F.R.C.S. 1 Bath-place, Kensington, London, W.
Tregelles, Nathaniel. Neath Abbey, Glamorganshire.
1868. ‡Trehane, John. Exe View Lawn, Exeter.
1869. ‡Trehane, John, jun. Bedford-circus, Exeter.
1870. ‡Trench, Dr. Municipal Offices, Dale-street, Liverpool.
Trench, F. A. Newlands House, Clondalkin, Ireland.
*TREVELYAN, ARTHUR, J.P. Tyneholm, Pencaitland, N.B.
TREVELYAN, Sir WALTER CALVERLEY, Bart., M.A., F.R.S.E. F.G.S., F.S.A., F.R.G.S. Athenæum Club, London, S.W.; Wallington, Northumberland; and Nettlecombe, Somerset.
1871. §TRIBE, ALFRED, F.C.S. 73 Artesian-road, Bayswater, London, W.
1871. ‡TRIMEN, ROLAND, F.L.S., F.Z.S. Colonial Secretary's Office, Cape Town, Cape of Good Hope.
1860. §TRISTRAM, Rev. HENRY BAKER, M.A., LL.D., F.R.S., F.L.S., Canon of Durham. The College, Durham.
1869. ‡Troyte, C. A. W. Huntsham Court, Bampton, Devon.
1864. ‡Truell, Robert. Ballyhenry, Ashford, Co. Wicklow.
1869. ‡Tucker, Charles. Marlands, Exeter.
1847. *Tuckett, Francis Fox. 10 Baldwin-street, Bristol.
Tuke, James H. Bank, Hitchen.
1871. ‡Tuke, J. Batty, M.D. Cupar, Fifeshire.
1867. ‡Tulloch, The Very Rev. Principal, D.D. St. Andrews, Fifeshire.
1854. ‡TURNBULL, JAMES, M.D. 86 Rodney-street, Liverpool.
1855. §Turnbull, John. 37 West George-street, Glasgow.
1856. ‡Turnbull, Rev. J. C. 8 Bays-hill-villas, Cheltenham.
*TURNBULL, Rev. THOMAS SMITH, M.A., F.R.S., F.G.S., F.R.G.S. Blofield, Norfolk.
1871. §Turnbull, William. 14 Lansdowne-crescent, Edinburgh.
1873. *Turner, George. Horton Grange, Bradford, Yorkshire.
Turner, Thomas, M.D. 31 Curzon-street, Mayfair, London, W.
1875. §Turner, Thomas, F.S.S. Ashley House, Kingsdown, Bristol.
1863. *TURNER, WILLIAM, M.B., F.R.S.E., Professor of Anatomy in the University of Edinbugh. 6 Eton-terrace, Edinburgh.
1842. Twamley, Charles, F.G.S. 11 Regent's Park-road, London, N.W.
1847. ‡TWISS, Sir TRAVERS, D.C.L., F.R.S., F.R.G.S. 3 Paper-buildings, Temple, London, E.C.
1865. §TYLOR, EDWARD BURNETT, F.R.S. Linden, Wellington, Somerset.

Year of Election.
1858. *TYNDALL, JOHN, D.C.L., LL.D., Ph.D., F.R.S., F.G.S., Professor of Natural Philosophy in the Royal Institution. Royal Institution, Albemarle-street, London, W.
1861. *Tysoe, John. Seedley-road, Pendleton, near Manchester.

1872. ‡Upward, Alfred. 11 Great Queen-street, Westminster, London, S.W.
1855. ‡ *Ure, John.*
1859. ‡ *Urquhart, Rev. Alexander.*
1859. ‡Urquhart, W. Pollard. Craigston Castle, N.B.; and Castlepollard, Ireland.
1866. §Urquhart, William W. Rosebay, Broughty Ferry, by Dundee.
1873. §Uttley, Hiram. Burnley.

1870. ‡Vale, H. H. 42 Prospect-vale, Fairfield, Liverpool.
*Vance, Rev. Robert. 24 Blackhall-street, Dublin.
1863. ‡Vandoni, le Commandeur Comte de, Chargé d'Affaires de S. M. Tunisienne, Geneva.
1854. ‡Varley, Cromwell F., F.R.S. Fleetwood House, Beckenham, Kent.
1868. §Varley, Frederick H., F.R.A.S. Mildmay Park Works, Mildmay Avenue, Stoke Newington, London, N.
1865. *VARLEY, S. ALFRED. Hatfield, Herts.
1870. ‡Varley, Mrs. S. A. Hatfield, Herts.
1869. ‡Varwell, P. Alphington-street, Exeter.
1875. §Vaughan, Miss. Burlton Hall, Shrewsbury.
1863. ‡ *Vauvert, de Mean A., Vice-Consul for France. Tynemouth.*
1849. *Vaux, Frederick. Central Telegraph Office, Adelaide, South Australia.
1873. *Verney, Captain Edmund H., R.N. Rhianva, Bangor, North Wales.
Verney, Sir Harry, Bart. Lower Claydon, Buckinghamshire.
1866. ‡Vernon, Rev. E. H. Harcourt. Cotgrave Rectory, near Nottingham.
Vernon, George John, Lord. 32 Curzon-street, London, W.; and Sudbury Hall, Derbyshire.
1854. *VERNON, GEORGE V., F.R.A.S. 1 Osborne-place, Old Trafford, Manchester.
1864. *VICARY, WILLIAM, F.G.S. The Priory, Colleton-cresent, Exeter.
1868. ‡Vincent, Rev. William. Postwick Rectory, near Norwich.
1875. §Vines, David, F.R.A.S. Observatory House, Somerset-street, Kingsdown, Bristol.
1856. ‡VIVIAN, EDWARD, B.A. Woodfield, Torquay.
*VIVIAN, H. HUSSEY, M.P., F.G.S. Park Wern, Swansea; and 27 Belgrave-square, London, S.W.
1856. §VOELCKER, J. CH. AUGUSTUS, Ph.D., F.R.S., F.C.S., Professor of Chemistry to the Royal Agricultural Society of England. 39 Argyll-road, Kensington, London, W.
1875. §Volckman, Mrs. E. G. 43 Victoria-road, Kensington, London, W.
1875. §Volckman, William. 43 Victoria-road, Kensington, London, W.
‡Vose, Dr. James. Gambier-terrace, Liverpool.

1875. §Wace, Rev. A. St. Paul's, Maidstone, Kent.
1860. §Waddingham, John. Guiting Grange, Winchcombe, Gloucestershire.
1859. ‡Waddington, John. New Dock Works, Leeds.
1870. §WAKE, CHARLES STANILAND. 70 Wright-street, Hull.
1855. *Waldegrave, The Hon. Granville. 26 Portland-place, London, W.
1873. ‡Wales, James. 4 Mount Royd, Manningham, Bradford, Yorkshire.

Year of Election.

1869. *Walford, Cornelius. 86 Belsize-park-gardens, London, N.W.
1849. §WALKER, CHARLES V., F.R.S., F.R.A.S. Fernside Villa, Redhill, near Reigate.
Walker, Sir Edward S. Berry Hill, Mansfield.
Walker, Frederick John. The Priory, Bathwick, Bath.
1866. ‡Walker, H. Westwood, Newport, by Dundee.
1859. ‡*Walker, James.*
1855. ‡Walker, John. 1 Exchange-court, Glasgow.
1842. *Walker, John. Thorncliffe, New Kenilworth-road, Leamington.
1866. *WALKER, J. F., M.A., F.C.P.S., F.C.S., F.G.S., F.L.S. 16 Gillygate, York.
1867. *Walker, Peter G. 2 Airlie-place, Dundee.
1866. ‡Walker, S. D. 38 Hampden-street, Nottingham.
1869. *Walker, Thomas F. W., M.A., F.G.S., F.R.G.S. 3 Circus, Bath.
Walker, William. 47 Northumberland-street, Edinburgh.
1869. ‡Walkey, J. E. C. High-street, Exeter.
1863. ‡WALLACE, ALFRED RUSSELL, F.R.G.S., F.L.S. The Dell, Grays, Essex.
1859. ‡WALLACE, WILLIAM, Ph.D., F.C.S. Chemical Laboratory, 3 Bath-street, Glasgow.
1857. ‡Waller, Edward. Lisenderry, Aughnacloy, Ireland.
1862. ‡*Wallich, George Charles, M.D., F.L.S. 60 Holland-road, Kensington, London, W.*
Wallinger, Rev. William.
1862. ‡WALPOLE, The Right Hon. SPENCER HORATIO, M.A., D.C.L., M.P., F.R.S. Ealing, London, W.
1857. ‡Walsh, Albert Jasper, F.R.C.S.I. 89 Harcourt-street, Dublin.
Walsh, John (Prussian Consul). 1 Sir John's Quay, Dublin.
1863. ‡Walters, Robert. Eldon-square, Newcastle-on-Tyne.
Walton, Thomas Todd. Mortimer House, Clifton, Bristol.
1863. ‡*Wanklyn, James Alfred, F.R.S.E., F.C.S.*
1872. ‡Warburton, Benjamin. Leicester.
1874. §Ward, F. D. 6 University-square, Belfast.
1874. §Ward, John, F.R.G.S. Royal Ulster Works, Chlorine, Belfast.
1857. ‡Ward, John S. Prospect-hill, Lisburn, Ireland.
Ward, Rev. Richard, M.A. 12 Eaton-place, London, S.W.
1863. ‡Ward, Robert. Dean-street, Newcastle-on-Tyne.
*Ward, William Sykes, F.C.S. 12 Bank-street, and Denison Hall, Leeds.
1867. ‡Warden, Alexander J. Dundee.
1858. ‡Wardle, Thomas. Leek Brook, Leek, Staffordshire.
1865. ‡Waring, Edward John, M.D., F.L.S. 49 Clifton-gardens, Maida-vale, London, W.
1864. *Warner, Edward. 49 Grosvenor-place, London, S.W.
1872. *Warner, Thomas. 47 Sussex-square, Brighton.
1856. ‡Warner, Thomas H. Lee. Tiberton Court, Hereford.
1875. §Warren, Algernon. Naseby House, Pembroke-road, Clifton, Bristol.
1865. *Warren, Edward P., L.D.S. 13 Old-square, Birmingham.
1869. ‡*Warren, James L.*
Warwick, William Atkinson. Wyddrington House, Cheltenham.
1856. ‡Washbourne, Buchanan, M.D. Gloucester.
*WATERHOUSE, JOHN, F.R.S., F.G.S., F.R.A.S. Wellhead, Halifax, Yorkshire.
1875. *Waterhouse, Captain J. Surveyor-General's Office, Calcutta. (Care of Messrs. Trübner & Co., Ludgate-hill, E.C.)
1854. ‡Waterhouse Nicholas. 5 Rake-lane, Liverpool.
1870. ‡Waters, A. T. H., M.D. 29 Hope-street, Liverpool.

Year of Election.

1875. §Waters, Arthur W., F.G.S. Woodbrook, Alderley Edge, near Birmingham.
1875. §Watherston, Alexander Law, M.A., F.R.A.S. Brentwood, Essex.
1867. ‡Watson, Rev. Archibald, D.D. The Manse, Dundee.
1855. ‡Watson, Ebenezer. 16 Abercromby-place, Glasgow.
1867. ‡Watson, Frederick Edwin. Thickthorn House, Cringleford, Norwich.
*WATSON, HENRY HOUGH, F.C.S. 227 The Folds, Bolton-le-Moors.
WATSON, HEWETT COTTRELL. Thames Ditton, Surrey.
1873. §Watson, Sir James (Lord Provost). Glasgow.
1859. ‡WATSON, JOHN FORBES, M.A., M.D., F.L.S. India Museum, London, S.W.
1863. ‡Watson, Joseph. Bensham-grove, near Gateshead-on-Tyne.
1863. ‡Watson, R. S. 101 Pilgrim-street, Newcastle-on-Tyne.
1867. ‡Watson, Thomas Donald. 41 Cross-street, Finsbury, London, E.C.
1869. ‡Watt, Robert B. E., C. E., F.R.G.S. Ashley-avenue, Belfast.
1861. ‡Watts, Sir James. Abney Hall, Cheadle, near Manchester.
1875. *Watts, John, D.Sc. 57 Baker-street, Portman-square, London, W.
1846. §Watts, John King, F.R.G.S. Market-place, St. Ives, Hunts.
1870. §Watts, William. Oldham Corporation Waterworks, Piethorn, near Rochdale.
1873. *WATTS, W. MARSHALL, D.Sc. Giggleswick Grammar School, near Settle.
1858. ‡Waud, Major E. Manston Hall, near Leeds.
Waud, Rev. S. W., M.A., F.R.A.S., F.C.P.S. Rettenden, near Wickford, Essex.
1862. §WAUGH, Major-General Sir ANDREW SCOTT, R.E., F.R.S., F.R.A.S., F.R.G.S. 7 Petersham-terrace, Queen's-gate-gardens, London, W.
1859. ‡Waugh, Edwin. Sager-street, Manchester.
*WAVENEY, Lord, F.R.S. 7 Audley-square, London, W.
*WAY, J. THOMAS, F.C.S. 9 Russell-road, Kensington, London, S.W.
1869. ‡Way, Samuel James. Adelaide, South Australia.
1871. ‡Webb, Richard M. 72 Grand-parade, Brighton.
*WEBB, Rev. THOMAS WILLIAM, M.A., F.R.A.S. Hardwick Vicarage, Hay, South Wales.
1866. *WEBB, WILLIAM FREDERICK, F.G.S., F.R.G.S. Newstead Abbey, near Nottingham.
1859. ‡Webster, John. 42 King-street, Aberdeen.
1862. ‡Webster, John Henry, M.D. Northampton.
1834. ‡Webster, Richard, F.R.A.S. 6 Queen Victoria-street, London, E.C.
1845. ‡Wedgewood, Hensleigh. 17 Cumberland-terrace, Regent's Park, London, N.W.
1854. ‡Weightman, William Henry. Farn Lea, Seaforth, Liverpool.
1865. ‡Welch, Christopher, M.A. University Club, Pall Mall East, London, S.W.
1867. §Weldon, Walter. Abbey Lodge, Merton, Surrey.
1850. ‡Wemyss, Alexander Watson, M.D. St. Andrews, N.B.
Wentworth, Frederick W. T. Vernon. Wentworth Castle, near Barnsley, Yorkshire.
1864. *Were, Anthony Berwick. Whitehaven, Cumberland.
1865. ‡*Wesley, William Henry.*
1853. ‡West, Alfred. Holderness-road, Hull.
1870. ‡West, Captain E. W. Bombay.
1853. ‡West, Leonard. Summergangs Cottage, Hull.
1873. ‡*West, Samuel H. 6 College-terrace West, London, W.*
1853. ‡West, Stephen. Hessle Grange, near Hull.
1851. *WESTERN, Sir T. B., Bart. Felix Hall, Kelvedon, Essex.

Year of
Election

1870. §Westgarth, William. 10 Bolton-gardens, South Kensington, London, W.
1842. Westhead, Edward. Chorlton-on-Medlock, near Manchester.
Westhead, John. Manchester.
1842. *Westhead, Joshua Proctor Brown. Lea Castle, near Kidderminster.
1857. *Westley, William. 24 Regent-street, London, S.W.
1863. ‡Westmacott, Percy. Whickham, Gateshead, Durham.
1860. §Weston, James Woods. Belmont House, Pendleton, Manchester.
1875. *Weston, Joseph D. Dorset House, Clifton Downs, Bristol.
1864. §WESTROPP, W. H. S., M.R.I.A. Lisdoonvarna, Co. Clare.
1860. ‡WESTWOOD, JOHN O., M.A., F.L.S., Professor of Zoology in the University of Oxford. Oxford.
1853. ‡Wheatley, E. B. Cote Wall, Mirfield, Yorkshire.
1866. ‡Wheatstone, Charles C. 19 Park-crescent, Regent's Park, London, N.W.
1847. ‡Wheeler, Edmund, F.R.A.S. 48 Tollington-road, Holloway, London, N.
1873. ‡Whipple, George Matthew, B.Sc., F.R.A.S. The Observatory, Kew, W.
1853. ‡Whitaker, Charles. Milton Hill, near Hull.
1874. §Whitaker, H., M.D. 11 Clarence-place, Belfast.
1859. *WHITAKER, WILLIAM, B.A., F.G.S. Geological Survey Office, 28 Jermyn-street, London, S.W.
1864. ‡White, Edmund. Victoria Villa, Batheaston, Bath.
1837. ‡WHITE, JAMES, F.G.S. 14 Chichester-terrace, Kemp Town, Brighton.
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